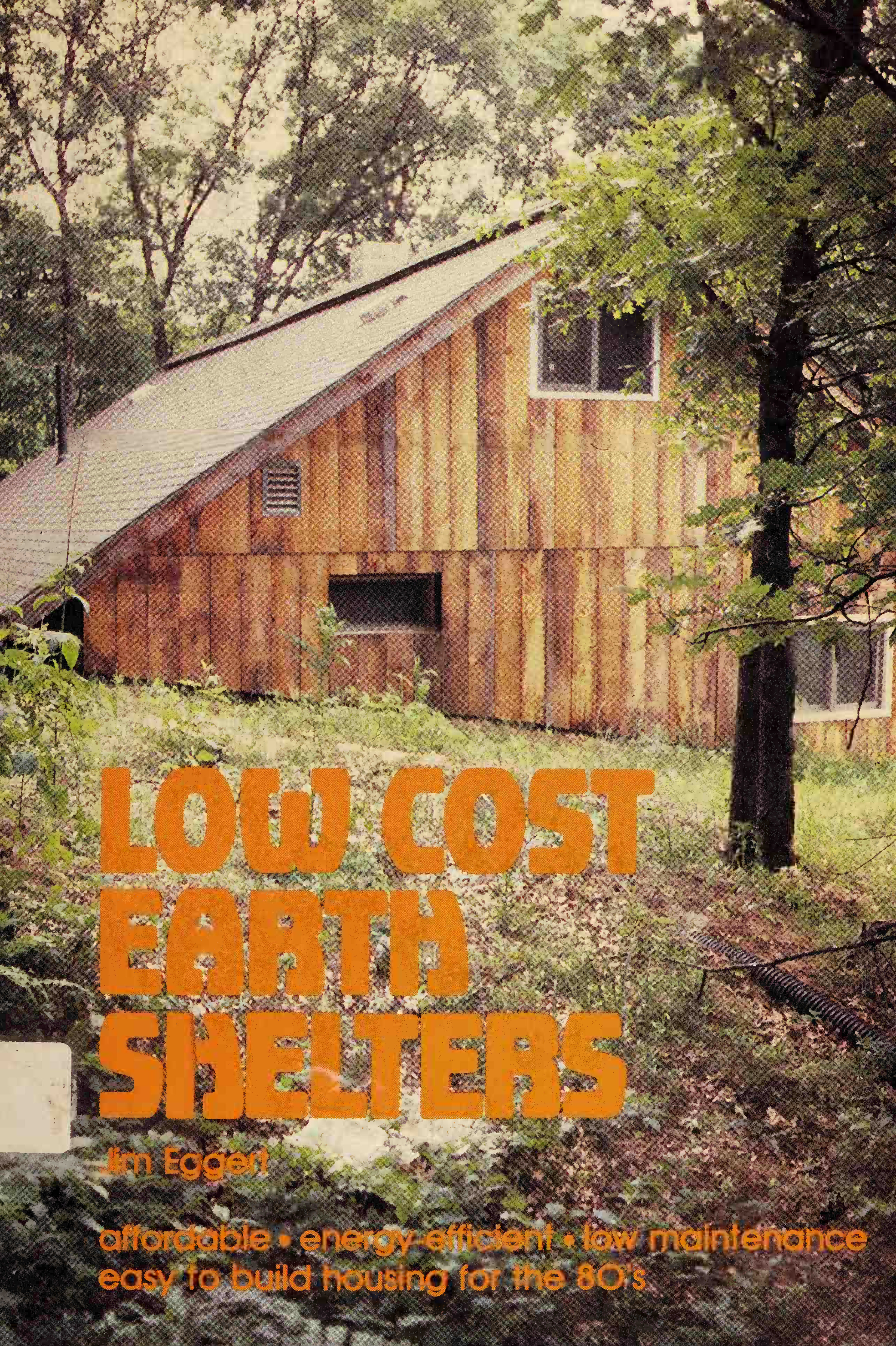

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Jim Eggert

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easy to build housing for the 80's

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Jim Eggert

Stackpole Books

LOW COST EARTH SHELTERS

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To My Mother,
Betty Eggert

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Introduction

> If it is asserted that civilization is a real advance in the condition of man, and I think that it is, it must be shown that it has produced better dwellings without making them more costly; and the cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run.
>
> Henry Thoreau

This book is about inexpensive, do-it-yourself earth shelters. Although much of the discussion will be on homes, there will also be material on structures for other uses.

There are undoubtedly many readers, with little building experience, who perhaps feel threatened by the idea of starting out with a project as large as a full-scale house. Attracted to the earth-sheltered concept, yet unsure of their construction abilities (and also of the relatively new underground building techniques), these readers may wish to begin with a less intimidating project such as an earth-sheltered workshop, office, studio, a guest house, or vacation home—any kind of living or working space where relative constancy of temperature is a definite economic as well as a comfort advantage. It should be noted that all the principles, methods, and techniques in this book can be applied with equal success to a variety of earth-sheltered buildings—large or small, for permanent habitation or just occasional use.

The book is divided into two major sections. The first, *Deciding To Go Underground*, looks primarily at housing. In these chapters, we will explore the philosophy and possibilities of building a small, inexpensive earth-sheltered dwelling. Included here will be information on site selection and planning. Also, we will take a careful look at the relative merits of having an earth roof or a conventional roof. Subsequent chapters will cover the pros and cons of various foundation types such as pole, concrete block, stone, treated wood, and formed concrete. In addition to looking at the theory of underground construction, we will also examine some actual experiences of owner/builders.

The second section, *Building an Earth-Shelter*, will be a detailed description of the methods, materials, and design of an earth-sheltered office I built in the summer of 1979. Especially for beginners, these five chapters should give the reader a feel for the joys and miseries of do-it-yourself construction.

Also included is a resource guide (Appendix 1) for those looking for additional information. Here we review books, magazines, and trade materials that should help you in all phases of planning and construction—from design, building, and waterproofing, to laying out plumbing, septic facilities, and landscaping.

Appendix 2 is designed for readers who are looking for alternative plans. Here you will find a variety of designs for small houses and other earth-sheltered projects.

I would like to take a moment to thank those who have assisted me in the making of this book including graphic artists Cathy Belongea, Paul Hansen, and Kris Wohnsen. Also a hearty "thanks" to Stan Smith, Pat Eggert, Paul Edmondson, Hans Timper, Stu Fullerton, and Jim Bjornerud, who were generous with their time and exceedingly helpful with their constructive comments.

In conclusion, it's my hope that you find this little book both stimulating and useful as you first contemplate and eventually build your own earth shelter. I wish you the best of luck.

Jim Eggert
University of Wisconsin-Stout
Menomonie, Wisconsin

Part I

DECIDING TO GO UNDERGROUND

. . . to my surprise and delight, underground architecture turned out to be even more cheerful and beautiful than I'd dreamed.
Malcolm Wells

Chapter 1

Underground Philosophy and Prerequisites

> "I knew one family there in Oklahoma City, a man and a woman and seven children lived in a hole in the ground. You'd be surprised how nice it was, how nice they kept it. They had chairs and tables, and beds back in that hole. And they had the dirt all braced up there, just like a cave."
>
> Mary Owsley
> as quoted by Studs Terkel in *Hard Times, An Oral History of the Great Depression*

Winter in northwest Wisconsin can be painfully cold. Even in the fall and early spring, someone who has lived in a milder climate will be surprised at how bitter it can be—especially when a gusty north wind sweeps down from Canada.

Thus it was no surprise when a friend of mine recently took me to the site of an original settler's pit-house that is today nothing more than a large hole in the ground surrounded by a young woods. I looked at the remains of this early settler's home and thought that it, indeed, offered some of the advantages that many cost-conscious families are seeking today.

—protection from the wind

—ease of heating by taking advantage of the relative warmth of the earth

—natural cooling in the summertime

—low cost

In addition to America's midwest, it's not difficult to find examples elsewhere of man's almost instinctive tendency to seek a safe, snug living environment underground, or partly underground. Historical illustrations abound in Sicily, Turkey, Italy and Tunisia.[1] Consider too the famous cliff dwelling pueblos of the American southwest or the earth-sheltered Navajo hogans in northern Arizona.

Yet, as practical as these earth-sheltered solutions were for their time and place, they will probably not convince modern families of the benefits of underground housing. Nor have our experiences with contemporary basements—which tend to be dark, cold, and damp—helped much either. Underground living must be something like living in a dark, clammy cave . . . or so people must think. This is unfortunate.

It's unfortunate because today there are designs and materials which make earth-sheltered living as totally satisfying as above-ground living. In short, an underground or earth-protected house can have both natural lighting and ventilation. In addition, it can be made effectively moisture resistant. Add to this list low noise level, low lifetime maintenance, fire resistance, and above all, energy efficiency, and you have housing that should satisfy most people's expectations.

You will not, however, get a home whose large and imposing visual appearance is designed to impress your neighbors. No, earth-sheltered homes are beautiful partly because they tend to almost disappear. They're more like the Chinese Taoist temples:

lovely because they do not stand out from the landscape—instead they are "nestled against the hills, back under the trees, blending in with the environment."[2]

Of course, some earth-sheltered houses may get their protection by simply pushing dirt up against the outside walls, a method commonly called "berming." But even this approach can be made appealing by planting grasses, shrubs, or even trees in the adjacent earth. Thus, these houses are attractive not through their imposing structure, but because of the landscape architecture around them, in front of them, and often above them.

Given the possibility of meeting modern expectations on ventilation, heating, natural lighting and dryness, the next question (at least for the reader of this book) is, can we do all this at a reasonable cost? I have found that many sources on underground housing imply that these requirements can only be met with a fairly large financial commitment. For example, the very fine book

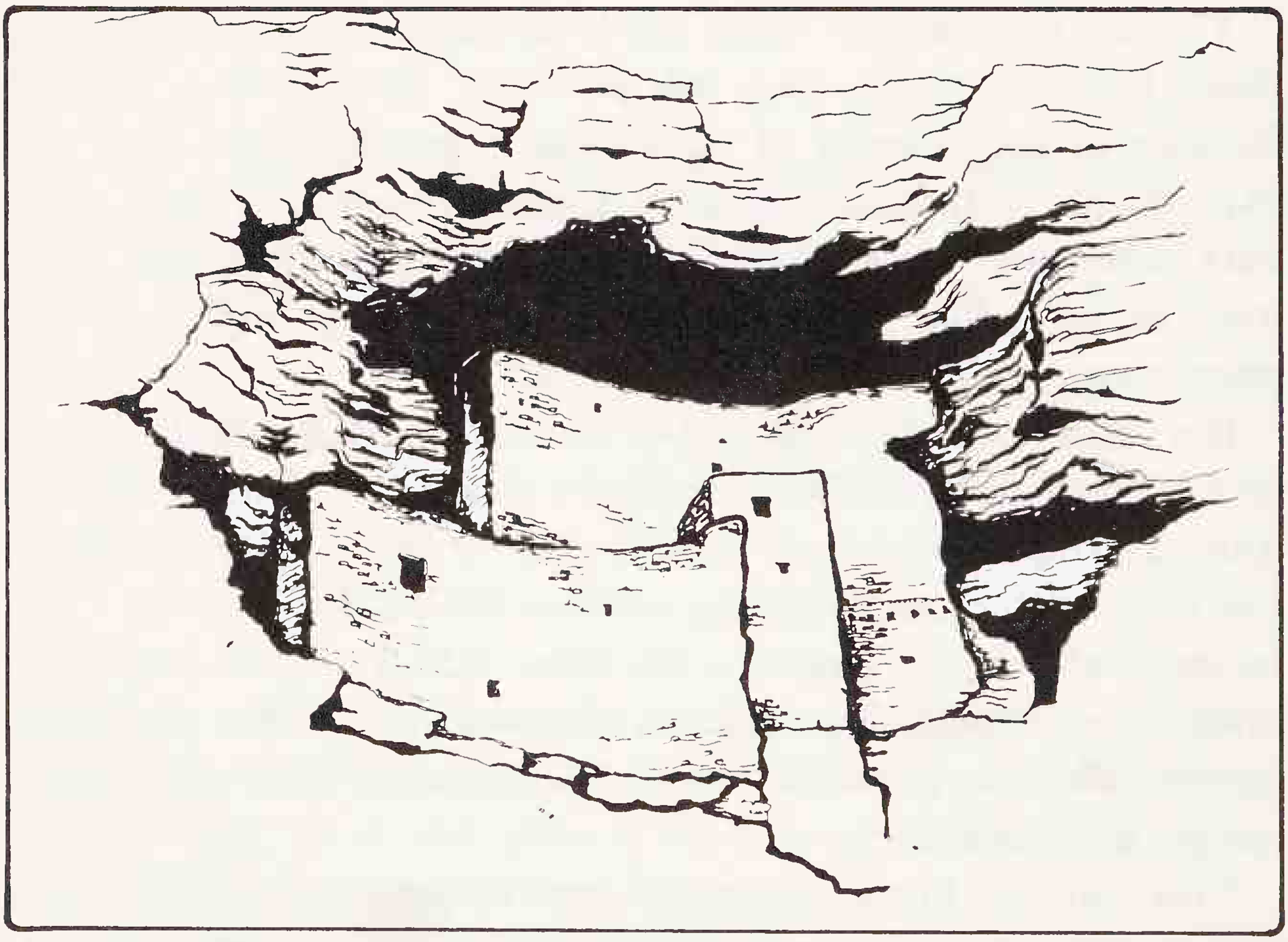


Figure 1-1 Montezuma's Castle, built by the Sinagua Indians near Camp Verde, Arizona, stands today as an example of an early earth-sheltered, passive solar dwelling.

from the Underground Space Center of the University of Minnesota, *Earth Sheltered Housing Design*, indicates that their homes will run from $40 to $44 dollars per square foot, about a third more than above-ground, conventional housing.

Fortunately, there are others who have managed to build quite satisfactory earth-protected homes for a third (or less) of the above dollar estimate. The specifics on how they managed to do this will be covered later in chapters three, four, and five. But first things first.

It would, I think, be helpful in this first chapter to outline some of the necessary preliminary considerations we should be looking at long before we begin our actual construction. These prerequisites include: land, working capital, and finally, the importantance of planning. Let's then begin with a brief look at the land question.

First Prerequisite—Picking a site

Sites for earth-sheltered housing can obviously come in many different forms, shapes, and locales—each possibility catering to different temperments, values, and finances. I have seen, for example, a fine underground home in a densely populated residential area (not far from a trailer court) and another aptly placed in a suburban setting. Malcolm Wells, a pioneer underground architect, suggests that you should not automatically neglect sites surrounded by pollution or noise. For example, Wells' first underground office in Cherry Hill, New Jersey is just a few feet from a busy highway.[3] Ugly duckling sites can cost less, and what is even more important, your care in landscape architecture can help repair the damaged environment.

Still, I suppose that most individuals (or families) have a "dream site" somewhere away from the suburbs, far from the noisy city—a green country acreage with a woodlot and some open land for organic gardening. Also of importance to some low-overhead, unconventional builders, the site should preferably be out of the range of building codes and inspectors. In addition, if you can find a site with a sand or gravel soil (one with good drainage), you will be reducing moisture problems and saving money on structural requirements at the same time. Finally, I think that most people visualize their earth-sheltered home built somewhere into a hillside with both a splendid view and good solar exposure.

Obviously there are not enough of these "perfect" sites to go around. More than likely you will have to make compromises such as building on level land (as I had to do with my office), or building closer to a city (to simplify commuting to work). Also you may not be able to avoid having to deal with building inspectors and state-wide building codes. Yet no matter what kind of possible building sites are available to you, I would recommend the following two items in regards to selection and planning.

First, carry a compass. Why should you know your directions? More than likely you will want to have the majority of your windows facing *south* in order to take advantage of the winter sun. This simple bit of knowledge will save you thousands of dollars in fuel costs over the life of your home. It's interesting to note than this passive solar know-how was recognized at least as far back as 350 B.C. in ancient Greece. Xenophon, in his *Memorabilia* quotes Socrates as saying, "in houses that look toward the south, the sun penetrates the portico in winter, while in summer the path of the sun is over our heads and above the roof so that there is shade."[4]

How frustrating it is then (particularly in a time of growing energy shortages) to see house after house going up here, there, and everywhere with their large windows on the *north* (or east or west) side of the house. A minor change in house placement or window design would, in many cases, make a tremendous difference in lifetime heating efficiency. Thus it is of great importance to look for a building site that allows unrestricted southern exposure. So take a compass!

Secondly, live on the site before making any final decisions. Become friends with your land. Attempt to understand as much as you can about the soil, the surroundings, and the changing weather during all seasons. Find out where the sun actually rises and sets in the winter and summer. How high will it get in June and how much overhang will you need to block it off during the hottest months? You can also figure sunshade requirements for your site by relatively simple math.[5]

In the winter, are there any unforeseen obstructions of the low December sun? What about the prevailing direction of the winter wind and the possible problem of drifting snow? In addition to observing the impact of sun and wind, be there when it rains. Where does the runoff water go? How well does the soil absorb moisture?

You may want to get a soil analysis not only for your future garden, but also to get information concerning your underground house. Sand, as we mentioned earlier, is excellent for drainage and digging. Good drainage will mean fewer moisture problems and also less potential damage from heaving frost. If you are building into a hill, there is also the possibility of exposing your back wall to ''soil creep'' pressures. Perhaps at one time or another you have seen a telephone pole angling away from a hill, as illustrated in figure 1-2.

The two worst soil types for a) soil creep b) moisture infiltration and c) frost heave are the clay and silt soils. In these heavy soils you can compensate for these problems by using drain tiles and by back-filling with coarse sand or gravel—but these precautions will obviously add quite a bit to your costs. For any questionable soil type, or if you suspect rock where you intend to put in your foundation, it is advisable to spend the money for a soil ''test-bore'' to investigate underground soil conditions. Precise knowledge of your soil is the only way a structural engineer or an experienced architect can design walls and footings with the necessary reinforcement to compensate for extraordinary stresses or unusual settling conditions. Many states also have completed detailed *Soil Surveys* through the Soil Conservation Service. If your area has one, it will be useful for both site selection and soil analysis. Check with your local county courthouse. Also a test bore will deliver the good or bad news as to whether you may be too close to the water table. For example, if the bottom of your footing is not at least three or four feet above water, you should not build underground on that particular site.

In conclusion then, a good understanding of site and soil conditions will undoubtedly be of great value to you when you begin designing and building your earth shelter.

Second Prerequisite—Money

There is no avoiding it, no way of getting around it—if you are building a home, you are going to need a good supply of cash before you start construction. Generally speaking, you will want a minimum of ten to fifteen thousand dollars for a self-built home of 1,000 square feet.

Money as cash or in a checking account is your most basic

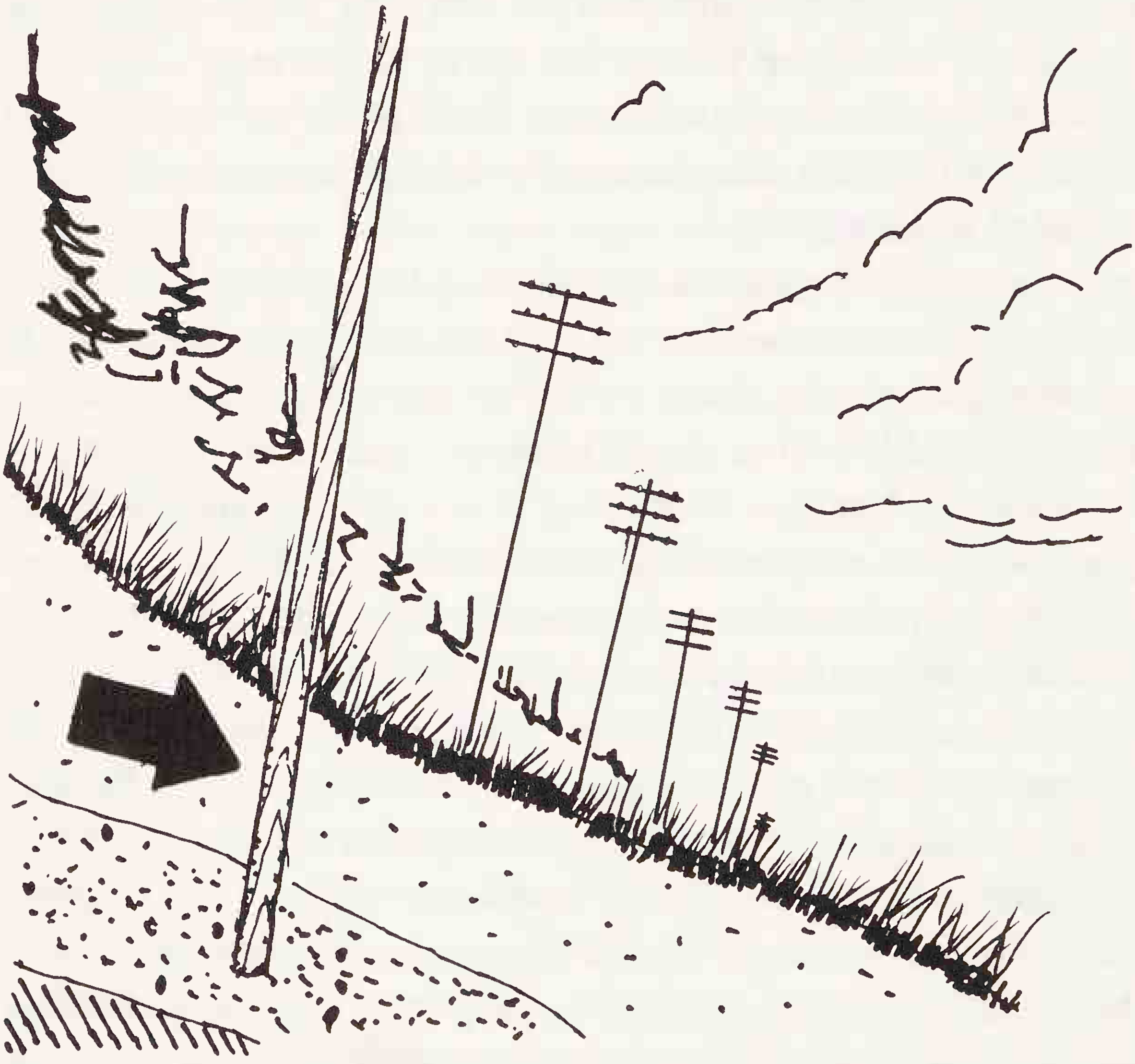


Figure 1-2 This is an example of "soil creep." The pressure is caused by the hill slowly flattening out as the moist soil "creeps" downward. Often these soil pressures can be tremendous.

building resource—one that will instantly command goods and services when and where you need them. To begin construction without having a minimal amount of cash will invite tremendous frustration (and you will certainly have enough frustrations as it is). But you're probably wondering (particularly after you have bought your site), how you can save an *extra* ten thousand dollars or more?

It's a good question in light of today's inflation—especially the high cost of basic necessities such as food, rent, and transportation. Yet, I have come across a surprisingly large number of individuals and couples who solved their cash problems with determination, discipline, and careful planning. Some of their methods might possibly be of help to you. They include:

—working hard for a short period of time in a relatively high-pay area such as Alaska or New York City while living in "poverty" and saving the surplus dollars.

—buying a parcel of land larger than you need, waiting a couple of years to let it appreciate, then selling off enough acreage to meet your working capital requirements.

—working out while living on your site in "substandard" housing such as a tepee, tent, or an old house trailer—better yet, build your workshop or garage, insulate it, and live there rent free as you save your salaries.

However you solve this particular problem, you should realize that it will definitely take time and also entail personal or family sacrifices.

Third Prerequisite—Planning

An initial commitment to careful planning is our third prerequisite. Let's assume that you have a site, you've explored its possibilities, and you are now ready to plan your house design. The first questions will undoubtedly be: "What kind of foundation will you have? Are you going 'true underground,' with soil on the roof, or are you planning to have a conventional above-ground roof?'' Hopefully the next three chapters will help you answer these questions.

Next, how do you want it to look when finished? How large a home will it be and what will your floor plan look like? On this last point, you may wish to get some advice from an experienced architect. In Appendix 2 you will find a sample of designs and floor plans of small (1,000 square feet or less) earth-sheltered homes. Of course, complete working drawings would probably be too expensive, but a modest floor plan sketch might well be worth the money.

There are some people who feel that it's important to make a small scale model of their house. Another method we've used is to make a reduced scale drawing of the floor plan on a piece of graph paper. We then cut out scaled-down furniture which can be shifted around on the graph paper. Some families enjoy visiting homes with similar room dimensions in order to get a feel for space size and other vital housing components. However you go about it, it's advisable to include the whole family in these initial planning and decision-making stages.

Early planning can also be applied to the procurement and storage of building materials. If you have cash on hand and start looking around early enough—say three to five years before construction—you can save a considerable amount of money. For example, watch the newspapers for slightly damaged or used materials. Buy out of season if possible. Watch for a dip in housing starts when there will be a temporary glut of everything from windows and wall studs to quality hardwood flooring.

Also keep your eye out for auctions and want ads in advertising flyers. I've had surprising success placing my own ad in the ``materials wanted'' section. There are frequently garage sales, truck sales, and going-out-of-business sales in most cities. Also check with nearby factories of manufactured items for seconds (windows, for example). One of the best methods of saving on lumber is to arrange with a local sawmill to cut rough-sawn boards, studs, rafters, etc. a year ahead of time. You can save considerably by drying the lumber yourself. You will also be getting full dimensional members instead of regular ''planed-down'' lumber that's sold at the building supply houses.

Finally, we should not neglect the possibilities of salvaging old buildings. My wife and I tore down a old farmhouse for our first building project and saved hundreds of dollars. You should realize, however, that salvage work is definitely not fun. It's dirty, dusty, and dangerous—but still an excellent way to save money and trees at the same time. There are some good tips on tools and salvage methods in Ken Kern's book, *The Owner Built Home*.

Other areas of planning include the buying or borrowing of the basic construction tools. Ken Kern's book has an excellent discussion on what you will need for basic building tools.[6] Arrange to have a large chunk of time free and clear for building. On this last point, I would suggest a ''house-building leave'' (akin to maternity leave) of an entire summer or more. You will find that trying to build without large blocks of time can be just as frustrating as starting without sufficient working capital.

In conclusion, it is these commonsense preliminaries, these essential prerequisities, which will make a tremendous difference in how smoothly it will all go when you finally begin construction. So let's now assume that you are ready to give serious consideration to initial planning. Certainly an early decision which must be made is whether you want to go completely underground or just earth-sheltered. The following chapter will be entirely devoted to helping you answer this fundamental question.

Chapter 2

The First Decision

> ''I don't know what color my office roof will be this fall. Last fall it was a solid yellow, done in masses of wild sunflowers. It was so intense it seemed almost to pulsate. . . Right now everything on the roof has been tinted with the tenderest and at the same time the most intense shades of green imaginable. We've had a lot of rain, and the roof looks very happy indeed.''
>
> Malcolm Wells

Your first design decision will probably be the following: do you want to build a ''true'' underground house, that is, one with six inches to two feet of earth on top, or do you want one that is simply ''earth-sheltered,'' with dirt bermed up on the sides, but having a conventional above-ground roof?

It's a very important question, one you will surely wish to give much thought. Your answer will, I think, be influenced by three crucial factors—first, how much you value landscape aesthetics; next, your financial situation, and finally, the question of energy efficiency and comfort. Let's begin with a detailed examination of the last point—underground efficiency.

Just why are earth-sheltered homes efficient in the first place? Many people are under the impression that it is the earth itself that insulates the house. This, however, is not exactly true. Moist earth, in fact, is a poor insulator compared with any standard insulating material. For example, it's been estimated that we would need three *feet* of moist earth to give us the same insulating capacity of just 1.5 *inches* of fiberglass batting!

What soil protection does do, however, is provide an effective barrier or *moderator* against widely fluctuating temperatures—temperatures which can range from winter's frigid subzero to tropic-like heat in the summertime. We find, for example, that at twenty feet below, the soil temperature will not vary more than three degrees (47°F–50°F) in northern regions. Of course you're not actually going to build that far down, yet even a modest subsurface depth will provide your home with surprising moderating effects.

A temperature monitoring experiment conducted by Dr. Lyle Feisel of Rapid City, South Dakota indicated a temperature variation of only nine degrees (31°F–40°F), seven feet down and two feet out from his heavily insulated underground wall. A sensor that was just four feet underground showed a variation of thirty-one degrees (39°F–70°F) while the above-ground temperatures ranged from a minus 30°F to a plus 104°F, or a total variation of 134 degrees.[7] You can now see the great efficiency advantage of living underground or partly underground.

In winter, your heating system need only increase temperatures a relatively small amount. And in the summer, you will be able to enjoy natural "air-conditioning" from the relatively cooler soil. In other words, underground homes enjoy the advantage of underground temperature stability—which translates into significantly lower utility bills year round. But there are other advantages too. For example, wind protection.

Winter wind robs your home of heat in two ways. First, by air infiltration, that is, by blowing cold air through the cracks and crevices, around windows, doors, siding, and so forth. And secondly, you lose heat when the wind zips past the sides of a conventional above-ground home. Rapid air movement creates a relatively low outside air pressure, and the resulting *higher* pressure inside forces your hot air out. Try blowing across the top of a long strip of paper: watch the sagging end ''mysteriously'' rise as your ''wind'' creates low pressure on top, while higher pressure underneath pushes the paper up (just as it pushes warm air out of your home).

Returning once again to the question of an earth roof. In terms of efficiency, putting soil on top will simply give you *one more side* of your house (the ''roof side'') and the extra efficiency advantages (moderating effect and wind protection) as outlined above. The other earth-covered walls and floor will, of course, be energy efficient in these terms already.

No doubt that when you design a house to have the roof earth-protected (as well as having your walls sunk somewhat deeper into the ground), you will have a more energy efficient home; but the important question is whether this added efficiency justifies the structural changes you must make to support an earthen roof.

If, for example, you decide to put two feet of earth on top, then add the inevitable moisture weight, you will need to design a roof capable of supporting at least 200 pounds per square foot! And obviously you cannot be too careful about the possibility of a collapsed roof. The Ubahn underground houses of Granite City, Illinois are designed for an additional 127 pounds/sq. ft.—a roof designed to hold a total of 327 pounds/sq. ft.! The ''safe-margin rule-of-thumb'' for earth loads in northern snow regions is to calculate an 80 lb./sq. ft. ''live'' load, then add 10 lb./sq. ft. for every inch of earth. Two feet of earth would therefore be 320 lb./sq. ft. (with the safety margin included).

With such tremendous support requirements, the inexperienced builder should obviously get the opinion of a structural engineer before he or she decides on the roof design. Most true underground houses in fact use prestressed concrete planks for their roofs. These sections are usually lifted into place by a crane—which adds considerably to the overall cost. A few uninhibited individuals that I have known (and read about) have poured their own concrete roofs using homemade forms, ready-mix, and lots of reinforcing steel. Prestressed concrete sections are probably outside the budgets of readers of this book; and your self-poured roofs are generally too difficult and dangerous for the beginner.

The other alternative, which some owner/builders have successfully incorporated, is the post, beam, and wood plank method—but again this can be relatively costly because of the great amount of lumber needed. There will also be the problem of having a large number of supporting posts in and about the interior living area. Still, builders like Robert Roy (whom we will look at more closely in the next chapter) apparently have solved the post and beam structural problem with a surprisingly small budget. Roy states a detailed argument for a modest roof thickness (6-12 inches) using plank and beam roofing construction.[8]

Another cost-related consideration of an earthern roof is waterproofing. Proven materials for moisture resistance can, unfortunately, be quite expensive. The recommended methods of the Underground Space Center include: a) built-up roofing (at least 3 ply asphalt and felt), b) butyl or neoprene membranes (rubber sheets), c) bituthene, and d) bentonite. The last mentioned, bentonite, is a clay material which tends to expand as it comes in contact with water (thus making for a self-sealing and continuous waterproofing material). In additions, bentonite has the advantage of being applied via spraying, trowling, or with cardboard-backed panels. (See Appendix 1 for a list of bentonite suppliers.) Anyone contemplating the use of these waterproofing materials should read chapter five of the Center's book (*Earth Sheltered Housing Design*) which describes their strengths and weaknesses, and the special precautions you should take before using them.

Although the above recommended methods are expensive compared to waterproofing a non-underground conventional roof, there is the possibility of using low-cost, 6 mil black polyethylene. Most experts feel that earth-exposed black plastic has a useful life of fifteen years for effective underground waterproofing. However, there has been little direct research on the matter.

Black plastic is usually used in conjunction with an asphalt or plastic-cement base (which incidently, can make for a difficult and messy application process). Also, any accidental punctures by man (backfilling etc.) or by subterranean animal, or any long term breakdown from expansion and contraction or from the acids in certain types of soils would quickly become an owner/builder's nightmare. In fact, any leak in any type of membrane or covering would turn into a sizable repair problem with tons and tons of dirt that would have to be removed before the leak could be mended. The waterproofing method least likely to develop long-term problems is the relatively expensive clay bentonite.

Consider too the insulation costs. If you use a steel reinforced concrete roof, you'll want to insulate with extruded or ''closed-cell'' polystyrene (often called by the Dow brand name ''Styrofoam''). Rigid styrene is by far the best method of insulating the *outside* of a concrete structure since it does not readily break down or absorb moisture, as does the less expensive product commonly called ''beadboard.'' The recommended roof insulation thickness is four to six inches. But unfortunately, extruded polystyrene is quite expensive. Using recent comparison prices, rigid styrene is about five times more expensive (comparable R value per square foot) than fiberglass batt insulation which would probably be used to insulate a conventional roof. The added efficiency of having a roof partly underground more than likely would not compensate for this large differential in insulation costs.

Here again is one more factor that points toward a conventional roof for owner/builders who wish to keep their costs low. Yet there is one more consideration as to whether you will want to go ''true underground'' or not—it's a factor that might in fact be the most important one for you. It is the question of inner and outer aesthetics.

No doubt there are a number of people who feel that there should be no compromise on the issue of an earth roof. They are, in fact, looking for a dwelling that will disrupt the landscape the least. Inherent in that value is a roof that will utilize precious rain water, one that can grow attractive shrubs, a garden, wild flowers, or just plain grass. Also of importance is the sense of quiet, low-maintenance, and the innate security of being truly sheltered by mother earth.

And then for some people, it's simply the sheer organic beauty of it all. No one, I believe, has expressed this idea so well as did architect Malcolm Wells when he wrote:

> I even tell lies myself. I hear myself telling people the main reason to build underground is energy conservation, and I talk a lot about all the money and natural resources you can save. Or that underground buildings are so quiet. Or that I build them to reduce the rainwater run-off invariably associated with impervious roofs. Or because all the sea and land surfaces of the earth were meant to be home to green plants and not to asphalt and concrete.
>
> All those reasons are true—and terribly important—but none is my main reason for going under. I'm always afraid to mention the real reason for fear it will seem frivolous and drive people away. So I wait until I know I'm among friends before I admit I do it primarily because it is so beautiful. *Please do not tell anyone this secret reason!*[9]

For those of you who share these strong aesthetic values and do not wish to compromise on an earthern roof, I can only say that you should indeed go ahead. Yet realize at the same time that you may well encounter extra problems and considerably greater expense. To keep your underground home within our low-cost guidelines, I might suggest that you could save money elsewhere on your home. For example, you might reduce the total size of your house. Or perhaps you could hold off on certain items such as cupboards and carpets—or delay installing a septic system-bathroom for a few years.

Readers committed to the aesthetics of true underground will be interested in the following chapter which examines the experiences (and books) of owner/builders Mike Oehler and Robert Roy—both of whom have managed to keep their subterranean homes well within a surprisingly modest budget. How did they do it? Let's take a look.

Chapter 3

True Underground

"Most men appear never to have considered what a house is and are actually though needlessly poor all their lives because they think that they must have such a one as their neighbors have."

Henry Thoreau

Mike Oehler

If the simple pit homes of the early American settler were the very least-cost dwellings using earth-sheltered principles, Mike Oehler's houses come in a close second. Mike is the author of *The $50 and Up Underground House Book.* What about this book with its incredible title? What about his homes?

Mike indeed does have plans for an extremely small house that actually cost him fifty dollars. Most of his book, however, describes the construction details of the more "expensive" variety which cost five-hundred dollars in materials. Besides describing these two homes, he also has plans for larger and of course, more expensive houses. But alas, what do you do with a book in which you read on page one:

> My dislikes may offend you. Task tisk. So that you may brace yourself, or so that we may start off on the wrong foot—which ever—I'll list a few here. I dislike businessmen, the American medical profession, "liberated" women, most architecture, agribusiness, 90 percent of industry. . .[10]

I don't think these comments are necessary. In fact, they might easily turn readers off right at the beginning—readers who might find this book quite useful. And after examining the book, I do think it is one that's worthwhile to buy. You may indeed not build Mike's way, but you'll undoubtedly find lots of seasoned thoughts on underground philosophy, on the frustrations of self-construction and finally, on how you can save money on materials and construction.

Let's then begin by asking the obvious question—just how does Mike build his homes so inexpensively? First of all, he digs by hand. For the larger house (370 square feet), it took him approximately three months. Next, he uses a pole framework for foundation and wall framing. On top of these poles are massive girders and above these, large beams.

Mike has a table of the different structural alternatives that are designed to hold two feet of dirt. One variation, using round posts, girders, and beams, entails the following requirements: a) six inch posts spaced six feet apart, both the length and width of the building, b) on top of these poles are nine inch girders spanning the length of the house, c) seven inch diameter beams are then placed on top of the girders. These beams are spaced two feet apart. And finally, d) roofing boards or planking ¾ inch thick.

Obviously there's quite a bit of wood in this system, plus lots of interior poles. Mike does have some good suggestions on how to find interior uses for these poles and also how to keep them out of the way.

Unfortunately, however, he has no practical solution to the problem of treating his poles. I appreciate Mike's honesty and concern for his readers when he warns against using penta and waterborne salt preservatives (which contain arsenic). He concludes that there ‘‘are no easy solutions’’ to the treatment question. He does, however, suggest one safe and inexpensive method (of questionable longevity): soaking the pole end in old crankcase oil and wrapping the end in polyethylene. I might suggest that if you use this method, you could apply an automotive ‘‘high detergent’’ additive to the oil. This helps break the oil's surface tension and increases its penetration into the wood.

At any rate, once you have ‘‘solved’’ the pole longevity question to your satisfaction, you simply place the poles into the ground, then shore up the walls by nailing rough-cut boards behind the posts—and at the same time stretch 6 mil black plastic on the outside of the wall. The roof is also made water-resistant with black plastic—using two layers with four inches of earth between.

Mike is careful to state that this system of ‘‘post-shoring-polyethylene’’ will *not* make the building waterproof, just moisture resistant. How then does he avoid having interior water problems? He minimizes infiltration with a unique design, one that allows water to drain into an uphill patio as can be seen in fig. 3-1.

From the drawing, you can see that any water coming from the hill area can be easily diverted or drained away within the patio area. I must admit that Oehler's design is a novel solution to a potential moisture problem that would otherwise be considerably expensive to remedy. The major disadvantage to this system is that you may not get that ‘‘spectacular view,’’ nor will you be able to take advantage of the passive solar energy factor discussed in chapter one.

Mike also saves money by not using insulation. Fiberglass would obviously be difficult to install since there are no wall studs or ceiling joists in the basic design. There would therefore be

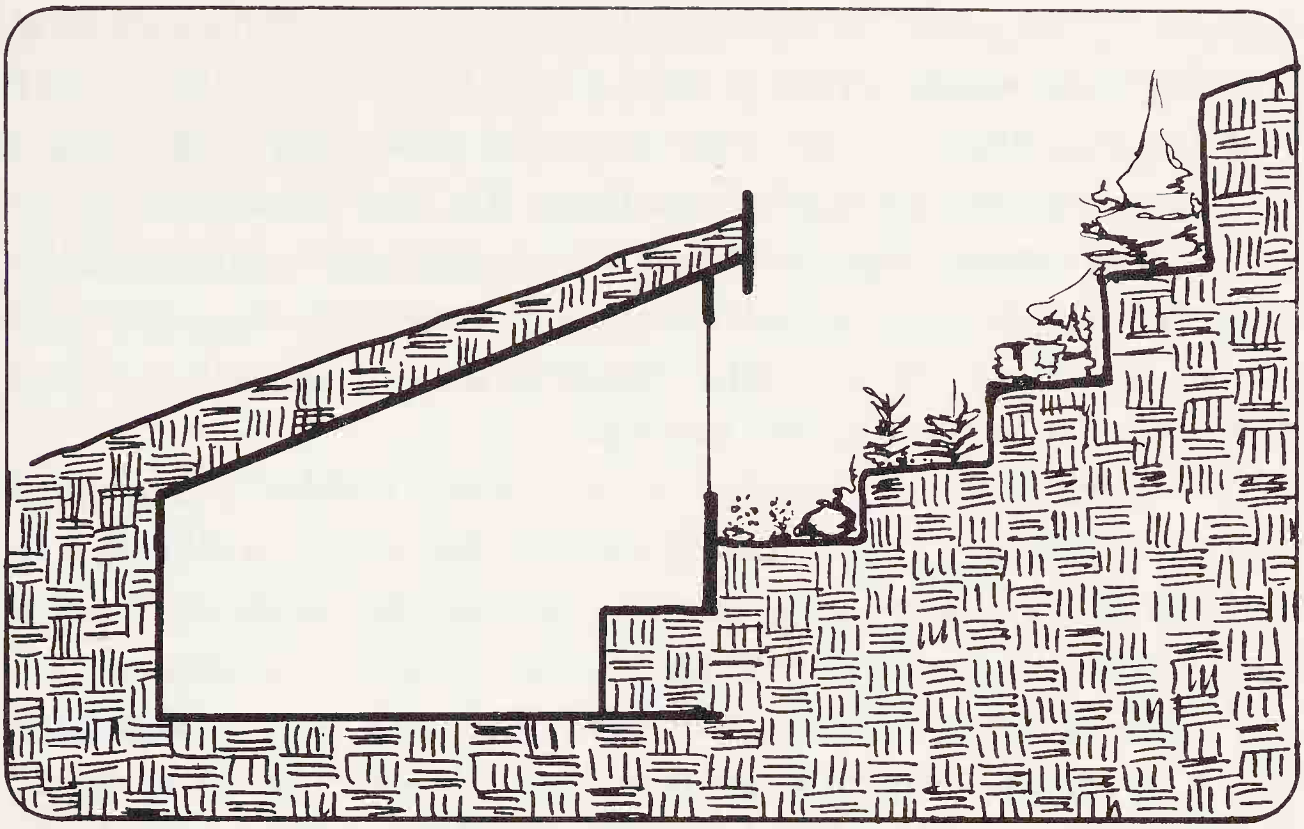


Figure 3-1 The uphill patio is Mike Oehler's unique method of preventing potential water problems.

considerable heat loss into the damp soil. Of course, the ground adjacent to his walls would, over time, begin to warm up; but the heat loss through the ceiling would translate into a continuous dissipation of interior heat and probably adversely affect the wintertime comfort level. Another potential problem would be the possibility of condensation and eventual decay of the roof planks. On the other hand, I keep having to remind myself that despite these conventional deficiencies, Mike has created a livable space for an extremely low outlay of cash. And judging by the color photographs near the end of the book, his $500 home looks surprisingly comfortable and snug.

Although there are a number of money-saving ideas in Oehler's book, I'll mention just one more—his "earth-carpet" floor. Mike's floor is simply leveled dirt with polyplastic and a rug on top. Again, it's simple, inexpensive, and relatively comfortable. And if you ever have to get at a malfunctioning water pipe, you simply roll up the rug and begin digging.

A family we know used this kind of floor and felt that its greatest disadvantage was in trying to get the floor level. When they finally had the money and time, they replaced their earth-rug system with a more conventional wood floor. Yet the cheaper floor arrangement served their needs for a number of years. Incidentally, this demonstrates one psychological advantage of a self-built home: one does not feel inhibited to make changes that reflect new knowledge, resources, and needs.

In summary then, what can we say about Oehler's ideas, and more specifically, how relevant are they for you? I would like to answer this question in a roundabout way. It begins with what a realtor friend recently told me.

''Jim,'' he said, ''even with high interest rates, the 'no mortgage home' concept will probably not appeal to even ten percent of the population.'' Most families, he assured me, have middle-class values and therefore want a house that comes as close to their ideal as possible. They not only want comfort, but also want a home that will appreciate and one that they will have little difficulty selling (to people like themselves). For these housing advantages, they're willing to commit a large portion of their life to pay off a long-term bank mortgage.

Now Mike's houses are not even in the usual ''no-mortgage'' category. They are ''sub'' no-mortgage. And my friend would therefore tell me that not even 1/100 of one percent of the people would be interested. I, too, would not build in this fashion—mainly because of the large amount of work involved versus the questionable life of the building.

But having said all this, I nevertheless want to commend Mike for his ideas and philosophy. He's carried the principle of simplicity in underground construction to a workable extreme. And when we find that his pole-frame underground house and other inexpensive construction ideas are just too much out of line with the norm, it's simply an indication of how entrenched we all are in the modern mold, how stuck we are in believing that the luxuries of yesterday must be today's necessities. It reflects how society has created such high expectations that we hardly recognize what we are giving up. Recall Henry Thoreau's comment that one test of a civilization is that it can produce good housing without it being overly costly, "and the cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run." Mike's Oehler's ideas are valid because they effectively meet this criteria. Indeed, I think Henry would have been pleased.

Robert Roy

But what if you still wish to go underground, yet you're looking for something a little bit more conventional and more durable, but you still want to remain within our low-cost guidelines? This question leads us to Robert Roy's home described in his book *Underground Houses—How to Build a Low-Cost Home.*

Whereas Oehler's approach was at times philosophical, nonconformist, and even irreverent, I found Roy's book more solid, straightforward, and generally better organized as he describes the step-by-step procedures he used to build a 900 square foot home for about $8,000.

As you can see, it's quite an attractive house with its modest gable roof, large windows on the south side, and its unique facade of short log ends and mortar, which the author calls "stovewood masonry."

Roy's support structure has a regular concrete footing and concrete block walls. There are massive 10 × 10 inch barn beams for his major supporting posts. Not including the end wall supports, he has a total of eight of these large posts within the house. These posts, in turn, support three roof beams of the same thickness which run north and south. These large beams are nine feet from each other and the same distance from the walls.

On top of the beams are heavy 4 × 8 inch rafters spaced thirty-two inches on center. Again, we should note the relatively large quantity of wood used here to support his earth roof. In order to keep total costs down, salvaging or arranging to have your own rafters and planking cut would be necessary. Then add to this

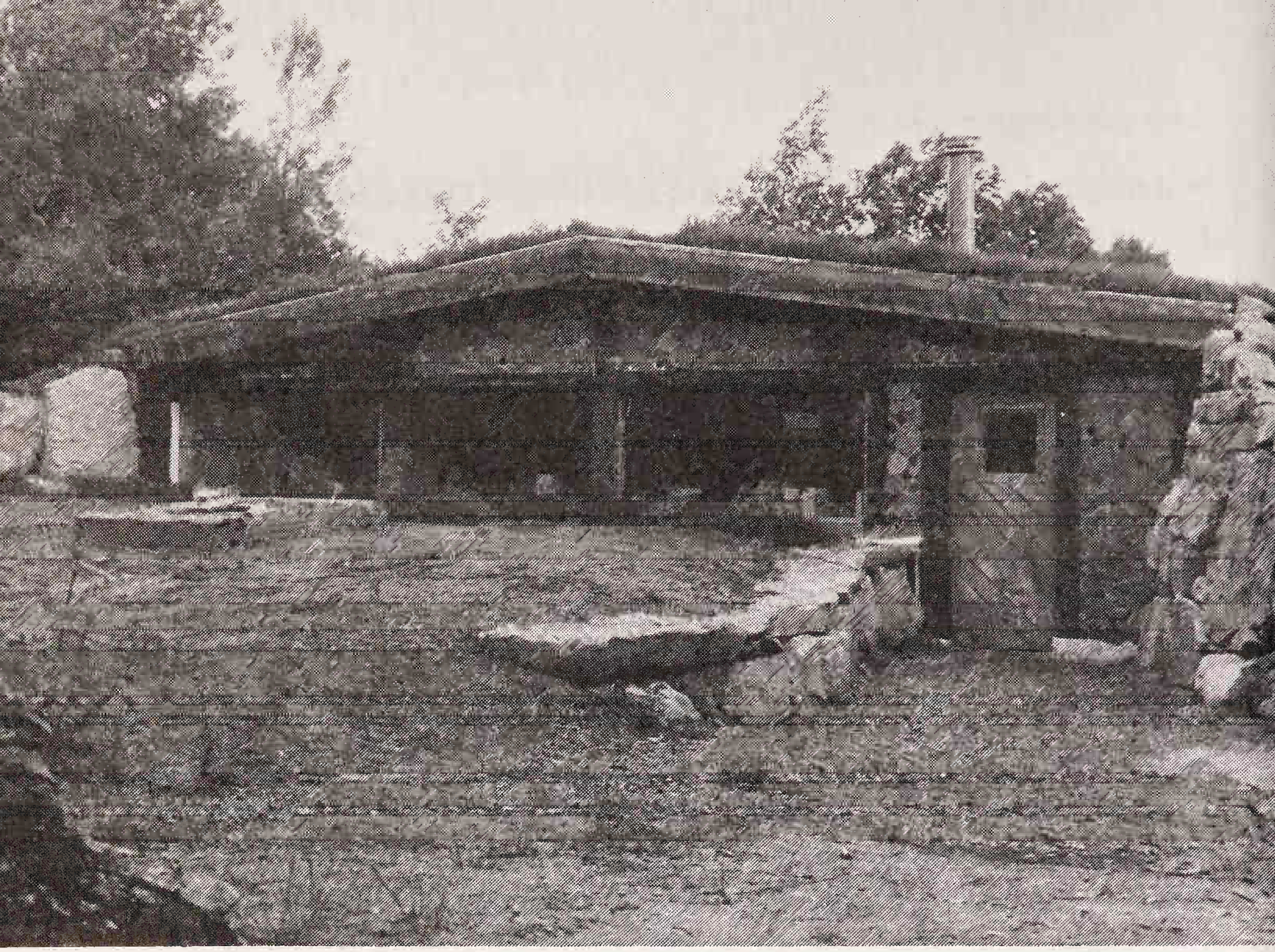


Figure 3-2 Rob Roy's $8,000 undergound house

wooden support structure, a solid deck of 2×6 planking or roof boards and you have a framework designed to safely hold *six inches* of earth and sod.

Continuing up from the roof planking, Roy put down three inches of rigid polystyrene insulation and then placed a layer of ⅝ inch particle board which serves as a base for waterproofing materials.

Throughout his book, I am impressed with Roy's simplified technical writing—writing which any uninitiated reader should easily be able to understand. From how to "square off" a footing, to establishing a sod roof, Rob is careful not to assume anything about his reader's knowledge and building experience. He is sympathetic with your fears and honest about his own mistakes.

For example, Roy's waterproofing method was not, as he readily admits, the best way to go. What he did was first apply a layer of fifteen-pound felt on the particle board, then a layer of goopy plastic roofing cement, and on top of that, a sheet of 6 mil black plastic. And to make extra sure, Roy repeated with a *second* layer of cement and plastic. Of course, he has a good watertight roof now. But he discovered that spreading a total of 250 gallons of roofing cement was more difficult and far messier than he had ever anticipated. ''All in all,'' Roy concludes, ''I wouldn't recommend this work to anyone I wanted to keep as a friend.''

Next time around, he thinks he would try a bituthene covering, which consists of a single sheet of polyethylene-coated rubberized asphalt. More expensive? Yes. But infinitely easier to apply for inexperienced owner/builders. Incidentally, Roy's walls are waterproofed by the same plastic-cement-polyethelene method mentioned above, but here he uses one layer instead of two.

So much for his difficulties. What about Roy's successes? I would like to take a moment to discuss what I feel is Roy's real contribution to the low-cost underground philosophy—how he built his walls.

Recall that Roy used concrete block. Yet block walls laid up without reinforcing (only mortar between the blocks) can make for serious problems later on. It's quite likely, for example, that frost heaving or water pressure, or even the slight shifting or creeping of the soil will, sooner or later, exert enough force to break the mortared bonding between some of the blocks. The results? Cracks. You've probably seen these random cracks in basements or possibly in a garage wall built into the side of a hill.

So how did Roy manage to build a sturdy concrete block wall? He used *surface-bonding cement*. This is a cement product permeated with strands of fiberglass that one applies to *both* sides of a concrete block wall that has been laid up ''dry''—without any conventional mortared joints.

There are a number of companies that make this special block bonding material—some of the more popular brand names include ''Fiberbond'' (Mountain Stone Manufacturing) and ''Surewall'' (Bonsal Company) and ''Conproco'' foundation coat. See Appendix 1 for more information on these companies. You can also make this product yourself using correct proportions of cement, lime, calcium stearate, glass fiber and calcium chloride as de-

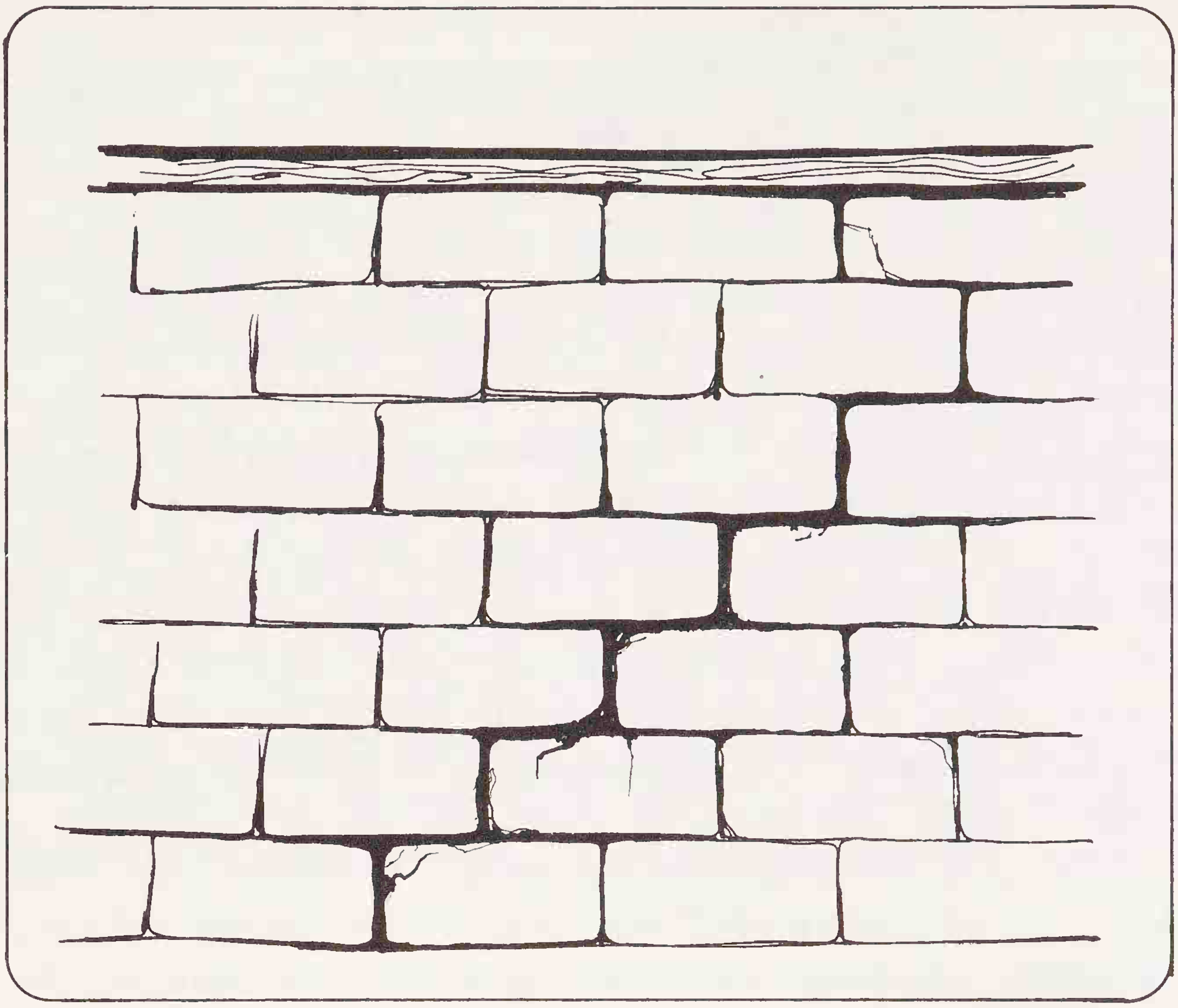


Figure 3-3 Unreinforced concrete block walls without surface bonding can often result in large cracks.

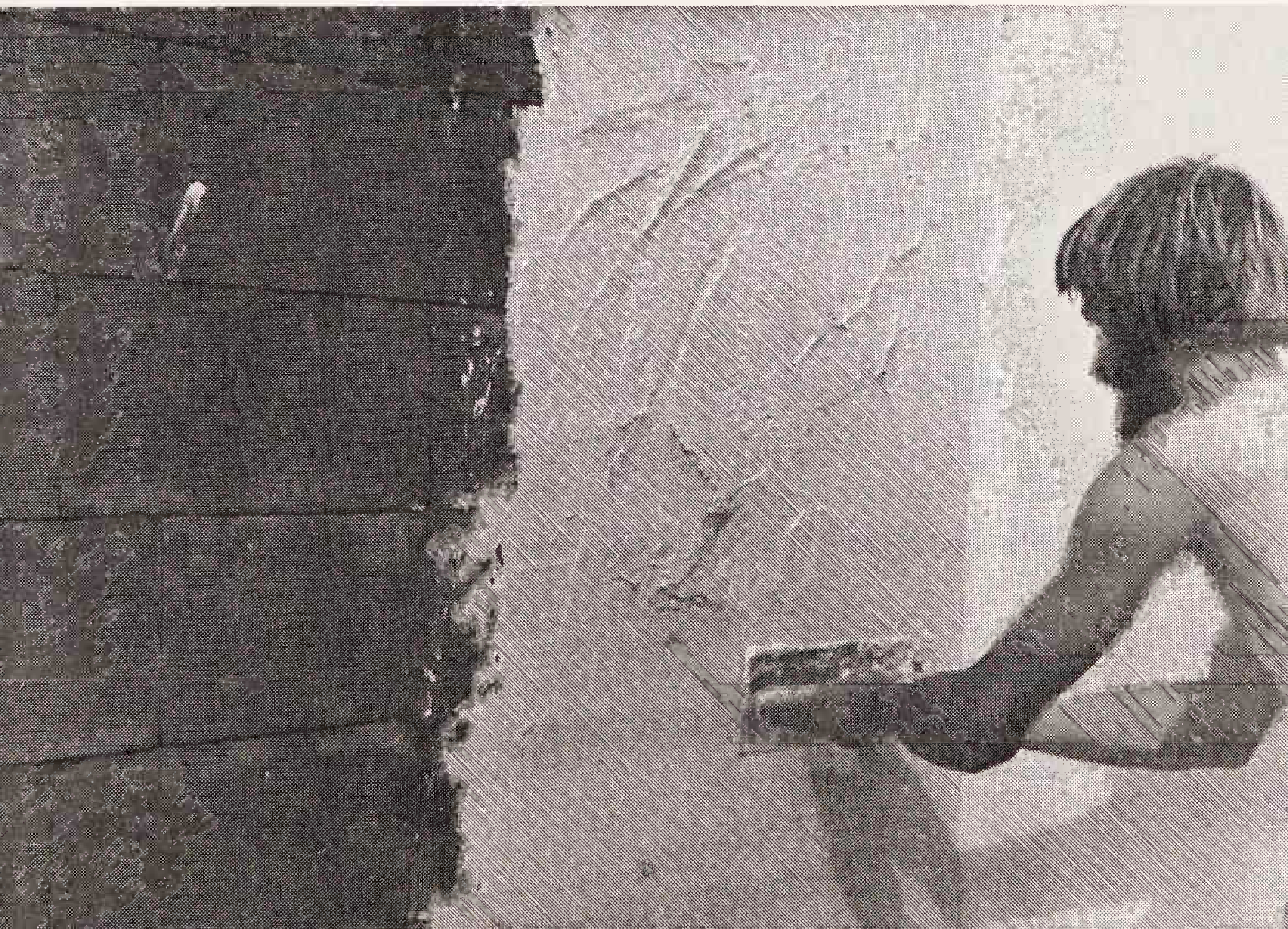
scribed in the sixth chapter of Roy's book. There are, however, advantages to buying this product premixed as you'll be sure to get the precise proportion of ingredients.

To build a wall using this remarkable material, you begin by placing your first course of blocks in regular mortar. But from there on, you will simply stack the blocks "dry"—being careful to plumb and level the wall as you go. Next, you mix the bonding cement with water using about one and one-half gallons of water to a 50 pound bag. Now wet the blocks down with a hose and trowel the mixture onto both sides of the wall. The thickness of the surface-bonded coating need be only ⅛ of an inch.

When the bonding material dries, you will have a wall that is considerably stronger than a regular mortared concrete block wall. In addition, the continuous bonded surface gives you an extra advantage of being moisture resistant (although further waterproofing of some kind is usually recommended). Surface bonding may also offer some protection from radon gas infiltration which may be slowly released from both the soil and from the concrete itself.[11]

From everything I have heard about this product, it appears to be an excellent low-cost method of building sub-surface walls. In addition, it's fairly easy to apply—even for the beginner. I tried surface bonding cement (Surewall) on a course of blocks on the south side of my office/workshop and found it to be relatively simple to use and quite durable. If you are still skeptical, Roy recommends that you write for a U.S.D.A. Research Bulletin #374 called "Construction with Surface Bonding." (See Appendix 1.) I might add that I obtained some excellent material on

Figure 3-4 There are several advantages to applying bonding cement to a block wall. The wall will be stronger and moisture resistant, and the method of application is relatively easy for inexperienced builders.



Surewall from the W.R. Bonsal Company in Lifesville, North Carolina.

Roy used twelve inch block and reinforced his walls by filling a block's core with concrete and reinforcing steel every ten feet. At this point, I would also recommend pouring sand into all the empty cores in order to increase the thermal mass of your walls. The use of 12 inch block plus steel reinforcement and surface bonding put Roy's walls close to the strength of poured concrete.

In conclusion, I believe that Roy has hit upon a good method for constructing low-cost underground walls. Perhaps you will want to seriously consider his building methods. Yet even if you don't, I'd still recommend buying his book and reading it for the clear explanations of how he solved a variety of problems—from installing plumbing to final landscaping—problems that you will undoubtedly encounter yourself as you begin building your low-cost earth shelter.

Chapter 4

Stone Foundations

"Stone houses are poised, dignified and solid—sturdy in appearance and in fact, standing as they do for generations."

Helen and Scott Nearing

When talking to or reading about people who have built with stone, you discover something unusual. These builders are not only pleased with their completed stone walls, but they also get excited, even thrilled by the building process itself. Consider for example the following quote from Helen and Scott Nearing's book, *Living the Good Life:*

> A little care resulted in attractive arrangements of the stone making up the outside wall, and it was always exciting when the forms first came off to see the varied patterns and colors.

> It was like the unveiling of an art work. We still recognize certain rocks as old friends and delight in many sections of our own buildings. We knew our houses from inside out and placed each rock with loving care.[12]

In the case of Carl Schwenke, co-author of *Build Your Own Stone House*, we find a stone-enthusiast who (in the book's first paragraph) confesses that for him, "messing about with stones is an addiction," and for the stone addict, "putting stones into a wall is an elemental act of life." In addition, Schwenke feels that this kind of work "rekindles the body" and "heightens one's awareness." Rarely have I heard or read about anyone building with "ordinary" wood or concrete sing so eloquently about the joys of hard work. Indeed, there seems to be something special about the making of a stone wall.

It is this feeling of creating something extraordinary out of common field stone—plus the fifty percent or more savings (over conventional "ready-mix" concrete walls) that may also convince you to consider a stone wall for your building project. Although the Nearings and Schwenkes both built their homes above ground, there is no reason why one could not incorporate stone wall techniques in an earth-sheltered home or other underground project. If you do go with stone, you would obviously want to reverse the Nearing's wall system, i.e., you would want to have the attractive stone facing *on the inside* of the building while the outside wall remains smooth for easy application of waterproofing materials and insulation.

How then did the Nearings, Schwenkes, and other inexperienced builders construct sturdy and attractive stone walls? They did it by using the so called "slip-form" method originally invented by the early 20th century American architect, Ernest Flagg. In his now famous book, *Small Houses*, Flagg describes the construction of his walls as laying up a "mosaic" pattern of field stone between two slip forms. A set of forms (2×6, 2×8, or 2×10 inch planks) are filled with stone and concrete and then allowed to dry. The forms would then be "slid" up 4×4 inch

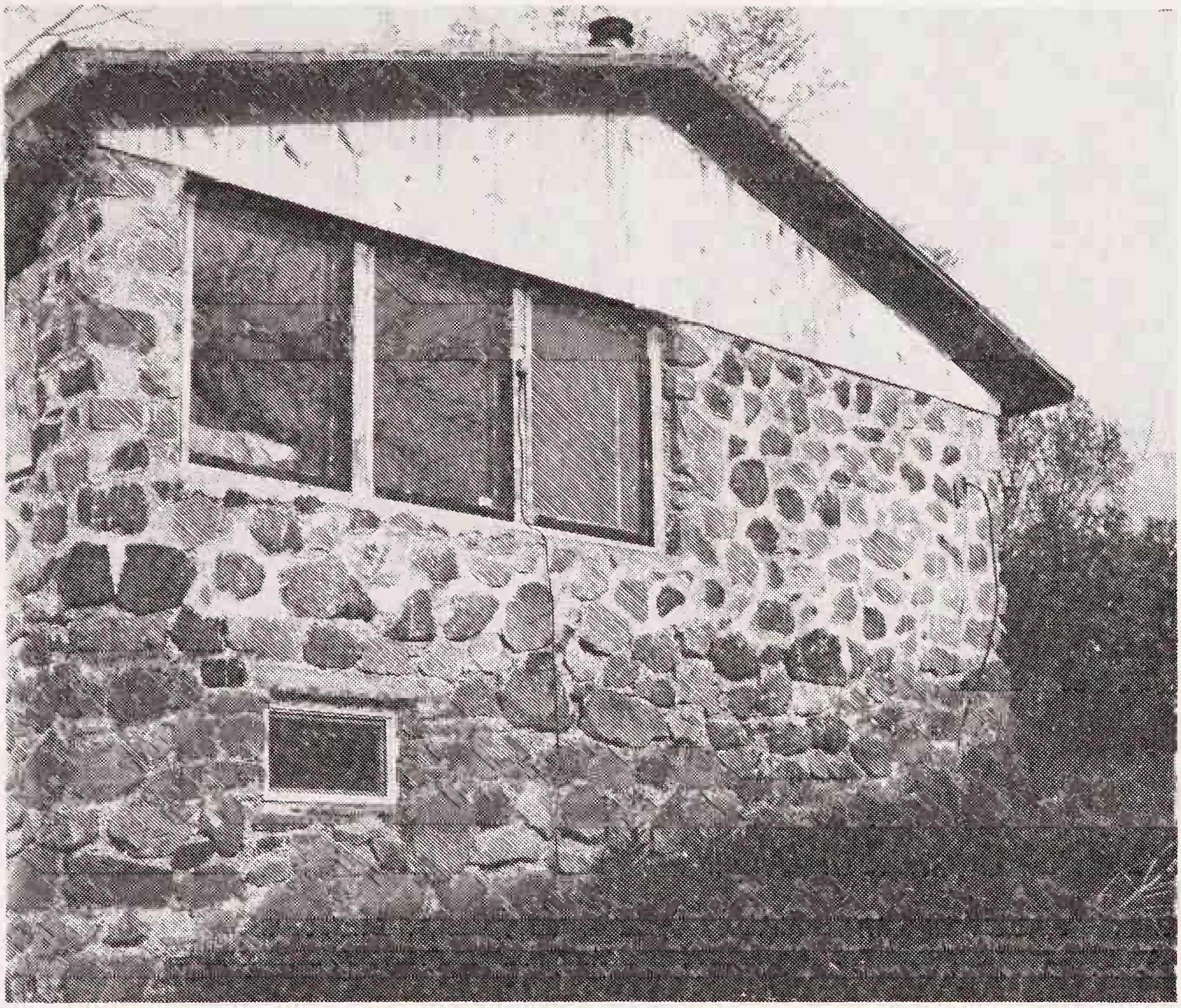


Figure 4-1 This is an example of an attractive, low-cost stone wall that was constructed using the slip-form method.

uprights or studs in preparation for another round of stone-laying and concrete fill. This process would continue until the wall reached the desired height. In *Small Houses*, Flagg claimed that compared to ordinary stone masonry, his method proved to be "more speedy and economical than common methods, produces a better looking wall than ordinary rubble, and most of the work may be done by unskilled labor."

More specifically, the Flagg technique involved:

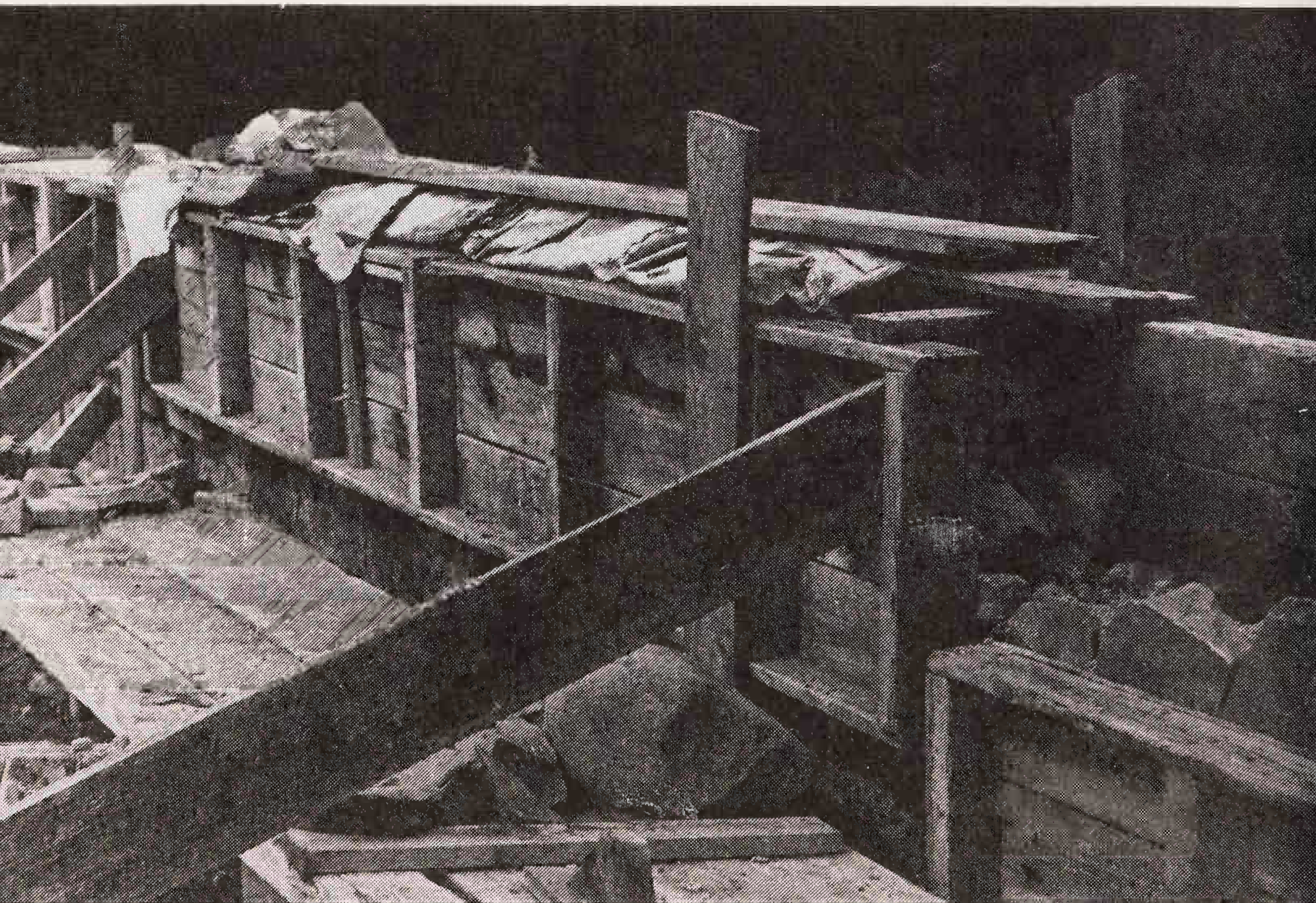
> placing stones in forms, with the flattest side flush with the outer face and shoveling in concrete behind them . . . they are put in dry, like pieces of mosaic, and mortar is squeezed into the joints afterward, then the forms are removed.[13]

It is this "mosaic of stone," specially chosen and cherished, and artistically placed that is the delight of the beginning stonebuilder.

The Flagg technique, in turn, was improved upon in the 1930's by Helen and Scott Nearing who devised their own slip-form system that a) did not need the relatively expensive 4×4 inch studs and b) incorporated lighter forms.

A number of years ago I recall reading chapter three of *Living the Good Life*—the chapter describing Nearing's construction techniques—and getting a feeling of awe. I was sure that this industrious and inventive couple must have had a special talent for building with stone. It was only when I visited their homestead in Maine that I discovered that their slip-form system was really quite simple. Below are a couple of photographs I took of their new garden wall under construction. Incidentally, the slip forms you see in the photos have been used year in and year out for almost a half century. As you can see, they were still going strong in 1980.

Figure 4-2 A side view of the slip-forms the Nearing's used to build a garden wall.



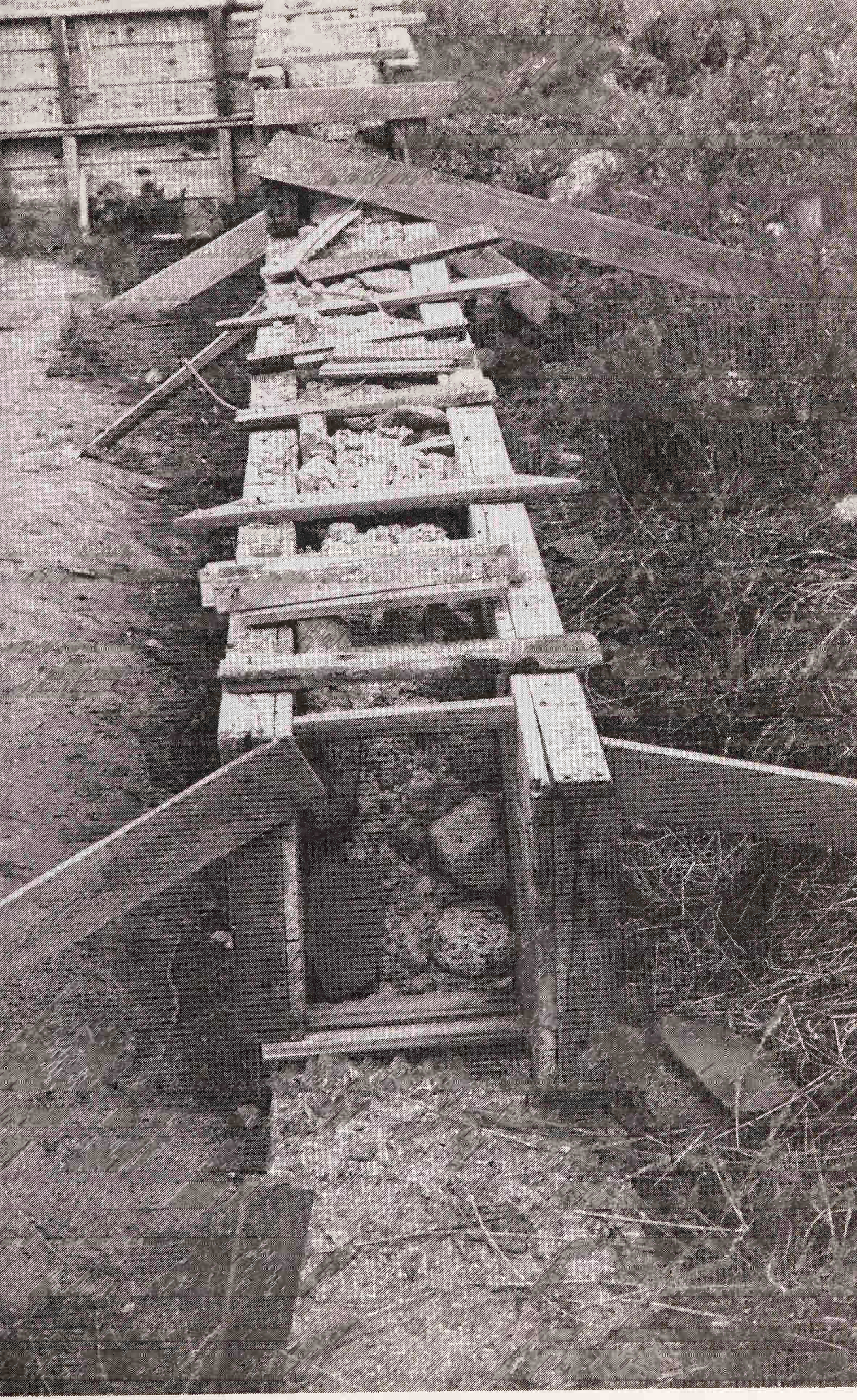


Figure 4-3 Top view of the Nearing's slip-forms

Since my visit to Maine, I've come across a number of other owner/builders who have successfully used Nearing's slip-form methods without any major problems. All of them, by the way, have recommended that anyone interested in formed stone work also read Carl and Sue Schwenke's *Build Your Own Stone House* and Lewis and Sharon Watson's *How to Build a Low-Cost House of Stone*. The Schwenke's book is somewhat longer and more technical. Both are full of ancecdotes and rich in detail; both offer much needed words of inspiration for those who are hesitant about building with stone.

Let's now take a closer look at how one goes about building a slip-formed stone wall. One of your first tasks is, of course, to make the forms. Metal forms are one possibility, offering light weight and flexibility. You can find plans for a 4 foot long metal form in *The Owner Builder's Guide to Stone Masonry*.[14] Wood forms, another alternative, can be constructed out of 1 inch boards or ¾ inch plywood. As you can see in the Nearing photograph (fig. 4-2), there are three 6 inch boards in each of their forms. The forming boards are framed by a 1 × 3 inch perimeter board with 2 × 3 inch studs every two feet, to give the forms durability and rigidity. Most people today use the more common 2 × 4 inch stock for their perimeter board and studs.

The width of the forms will be the vertical distance that the wall rises with each "pour." The Nearing's forms were 18 inches wide, the Schwenke's, 19 inches. Watson's plywood forms were only 16 inches wide—making it possible to cut three 16 inch strips (8 feet long) from a single sheet of plywood. Although I know of one builder who used 21-inch-wide forms, anything larger than this would be too heavy as well as too deep to comfortably position stones near the bottom.

Standard form lengths are either 6 or 8 feet. In any extensive stone project you would undoubtedly need a variety of sizes. The Nearing's "form collection" ranged from 15 inches to 14 feet.

How many total linear feet of forms will you need? If you build according to the Nearing method—which rests one form on top of another (see background of fig. 4-3)—you would ideally have to make enough *sets* of forms so that their total length, when joined together, would extend *twice* around the total wall distance . . . or at the very least, enough forms to extend around two corners and on to a "natural break" such as a window, doorway, for example.

The Watsons, however, were able to get by with just half the above number because their forms rested on 2×2 inch uprights (similar to the original Flagg method) that were spaced four feet apart around the perimeter of the building. Each opposing form, in turn, was supported by wires looped around the 2×2's (fig. 4-4).

It might be worthwhile to mention here that some builders have used this slip-form method, not to build a stone-faced wall, but simply to save money by doing their own "stage-by-stage" forming, and then filling in the forms with their own homemade concrete. If there are no inner or outer stone facings to worry about,

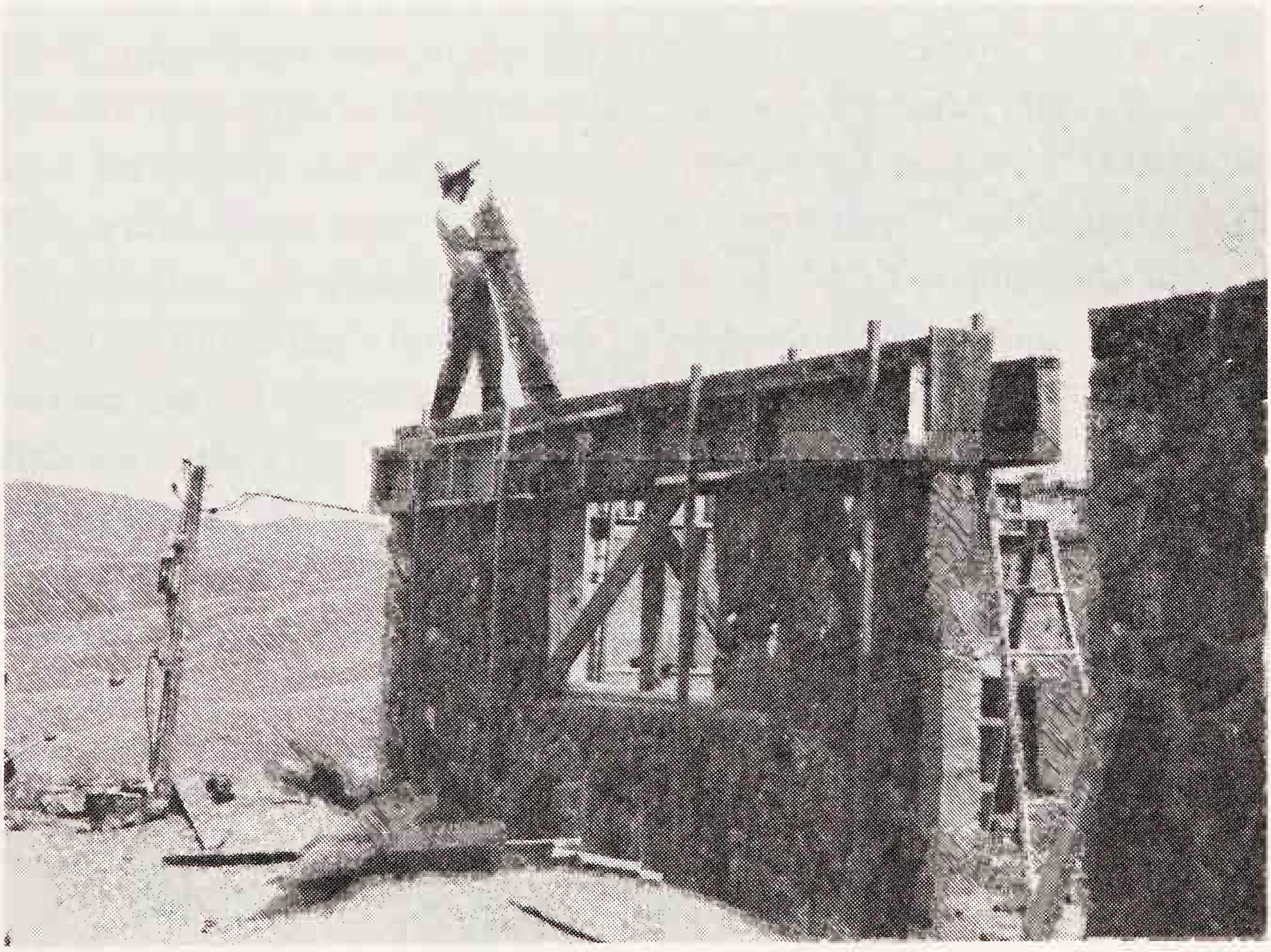


Figure 4-4 In Watson's form support system, the forms rest on 2″ × 2″ uprights spaced 4 feet apart, supported by wires, looped around the 2 × 2's.

a third method of securing the forms is possible—one successfully used by Dick Wohnsen, a rural owner/builder in our area. Like the Nearings and others, Dick's first set of forms rested on the footing. Before the pour, Dick drilled ⅜ inch holes four inches from the top of both inside and outside forms (fig. 4-5).

Then during the pour, Dick inserted ¼ inch carriage bolts approximately one inch into the concrete. Since his bolts were 2½ inches long, he had 1½ inches of threaded bolt sticking out of each side of the wall when the forms were pulled away. These bolts, in turn, served as secure resting points for the forms on the next go-around. Since the depth of the forms was 21 inches, each pour increased his wall a total of 17 inches. I'm sure there are other ingenious ways of solving the problem of how and where to rest the forms as they move progressively up the wall.

At some point you must, of course, determine how thick you want your walls. Nearing's walls were all a foot thick. The Watson's and Schwenke's (above ground) walls were ten inches thick. For earth-bermed walls, I would recommend a minimum wall thickness of fourteen inches—plus adequate steel reinforcing both vertically and horizontally. In addition, special attention should be paid to corners; here most stone builders put in at least a ⅜ inch steel rebar (extending three feet into each wall) every half foot or so. Keep in mind that thickness-for-thickness, a stone wall will *not* be as strong as a conventionally reinforced concrete wall. Underground builders must therefore compensate by increasing wall thickness and/or steel reinforcing. Faced with any unusual building conditions (possible settling, soil or water pressure problems), one would be advised to take the stone wall proposal to a structural engineer to get an estimate on footing and wall dimensions as well as reinforcing requirements.

Once you've determined your wall thickness, the next problem is, how to secure the forms so that they will make a rigid, rectangular 'trough.' The solution to this problem is surprisingly simple.

Forms on the *same* side of the wall are fastened together with ⅜ inch bolts, washers and wing nuts inserted into two ½ inch

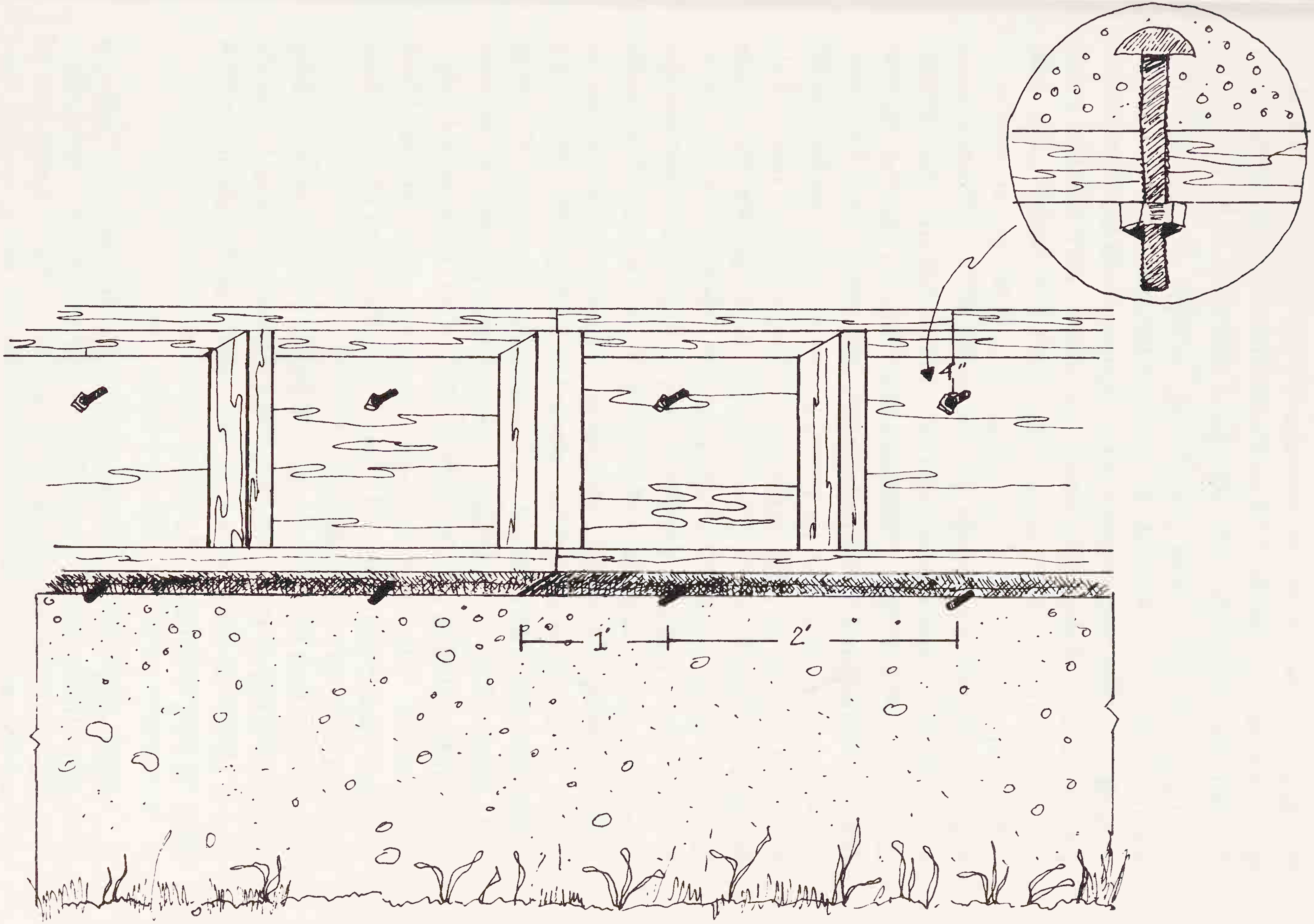


Figure 4-5 ¼" carriage bolts serve as secure resting points for slip-forms on the next go-around.

holes in the end studs. If you are resting one form on top of another (Nearing method), you should also bolt the upper form to the lower using the same size bolts and holes. The forms that are opposing each other are linked together by wires looped around the studs or lengths of 1 × 2's on the outside of the forms. (See fig. 4-2.) Two by two inch wood spacers hold the forms apart (the thickness of the wall); and then within the form, the wires are tightened with a 20 penny nail. Carl Schwenke quips that "those with a good ear will recognize a B-flat above middle C when the properly tightened wire is plucked." For the non-musical builder, common sense will undoubtedly tell you when everything is sufficiently tight. Although most builders recommend one upper and one lower wire tie on each stud, I have talked to some who have used just one tie that was placed near the bottom of the form. You can experiment for yourself on this point. Yet, however you go about it, don't forget to bridge the form tops together with any handy scraps of wood. (See fig. 4-3.)

Your forms must, of course, be leveled and plumbed and the corners carefully squared with a building line. You are now ready to begin filling the forms. Starting at a corner, you lay a couple inches of concrete a few feet along the bottom. The Nearing's concrete mix was 1-3-6 (cement-sand-gravel), while the Schwenke's was a somewhat richer 1-3-4. Lewis and Sharon Watson found that it was much easier to use an aggregate that consisted of twice as much sand as gravel, one that they said worked "more smoothly between the rocks." Pea gravel seems to work best for most builders.

Now you can lay your stones. To give you a general idea of how this is done, I'll simply quote an excerpt from the Watson's book. (Keep in mind, however, that your earth-sheltered wall's stone facing will be on the *inside*.)

> Once your forms are as solid, straight, and plumb as you can make them, wet down the foundation or previous wall surface (for better bonding) and pour in two or three linear feet of sticky concrete about 2″ thick. Press a *short* line of face

> stones into the concrete with the most attractive surface against the outside form. Place filler stones wherever you can behind the face stones and with your trowel work wet concrete into all openings behind, under, around, and between the stones. Don't let any stone touch another, at least over a very large surface, and make sure concrete is in *solid* contact with all stone surfaces. Simply continue this process until all forms are filled, then cover the top of your work with wet burlap, rugs, etc..[15]

And so your wall begins slowly to rise up from its concrete foundation. When the initial layer has been filled, repeat the process by raising the forms again and again—until the wall is complete. The remaining construction details can be found in the three books mentioned.

It should be obvious to the reader that this kind of stone work can be physically demanding. What needs to be emphasized, however, is that it can also be very time-consuming—especially when you consider all the preparation such as making the forms, hauling and cleaning stones, constructing scaffolding, and so forth.

I once asked my friend John Samuelson how long it took to build the walls of his partially earth-sheltered, two story, 24 × 24 foot workshop. We sat down with pencil and paper to estimate how many sixty-hour-weeks it took, from the building of the forms to the completed wall. We finally came up with an estimate of 1500 hours!

If, however, you have more time than money, and you can find yourself attracted to the aesthetics of stone, by all means, go ahead. The slip-form process, as I hope you can now see, is generally uncomplicated. The work can be exhilarating and the final wall will be something you will always be proud of.

The slip-form method is, of course, but one way to build with stone. There are other techniques that you also might wish to consider. Perhaps the best book available describing these alternatives is *The Owner Builder's Guide to Stone Masonry* by Ken Kern, Steve Magers, and Lou Penfield. It's a great source book, full of instruction and rich in photographs that capture stone's rugged beauty, durability, and integrity. Indeed, I doubt if anyone can read this book without wanting to begin some kind of stone project.

One technique described in *Stone Masonry*, a method that shows real promise for earth-sheltered projects, involves building up a stone facing against an insulated reinforced block or poured concrete wall (fig. 4-6).

The above technique has the following advantages: a) you start with a reinforced concrete or block wall which, compared to a formed stone wall, can be more accurately evaluated for underground stresses; b) for the beginning stone layer, a rock facing is perhaps the easiest and certainly the least time consuming of the stone-laying techniques; c) the inside of the wall stays dry; you can therefore use the less expensive ''bead-board'' for insulation; d) since the winter sun in northern regions penetrates only 2-3 inches into a masonry wall, the relatively thin stone facing makes an ideal solar heat container. Note too that once your interior stone facing is complete, you need not worry about installing any other type of interior wall.

Another method described in Kern's book involves laying up a stone facing on one side of a wall, while the other side is formed up with plywood backing. This backing, in turn, allows you to fill in the space—between the stone facing and the plywood—with rubble and concrete. When the plywood form is removed, your wall will have a flat side where you can easily apply waterproofing mastic, insulation, etc. This ''plywood backing'' technique was successfully used in the construction of a surprisingly inexpensive underground studio/workshop built by Doug Baty in western Montana. I visited Doug in the spring of 1981 and was quite impressed with his accomplishment—especially when you consider the he did not have any extensive stone building experience prior to the project. How did he do it? Let's take a detailed look.

The Baty Underground Studio/Workshop

First, a description of the structure: Doug's studio walls form

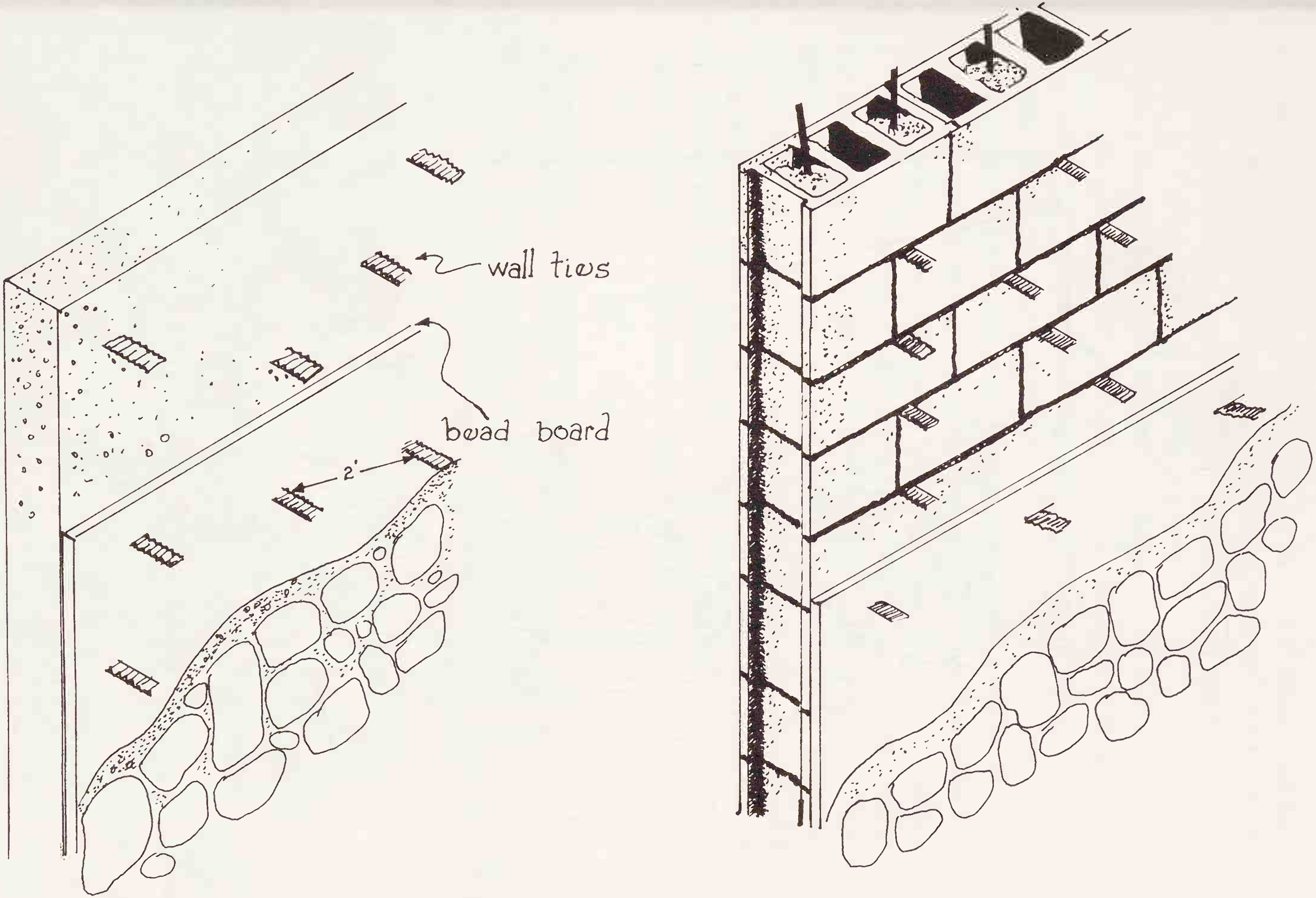


Figure 4-6 Stone facing against insulated reinforced block or poured concrete wall is a good technique for earth-sheltered projects. (Drawings are adapted from THE OWNER BUILDER'S GUIDE TO STONE MASONRY).

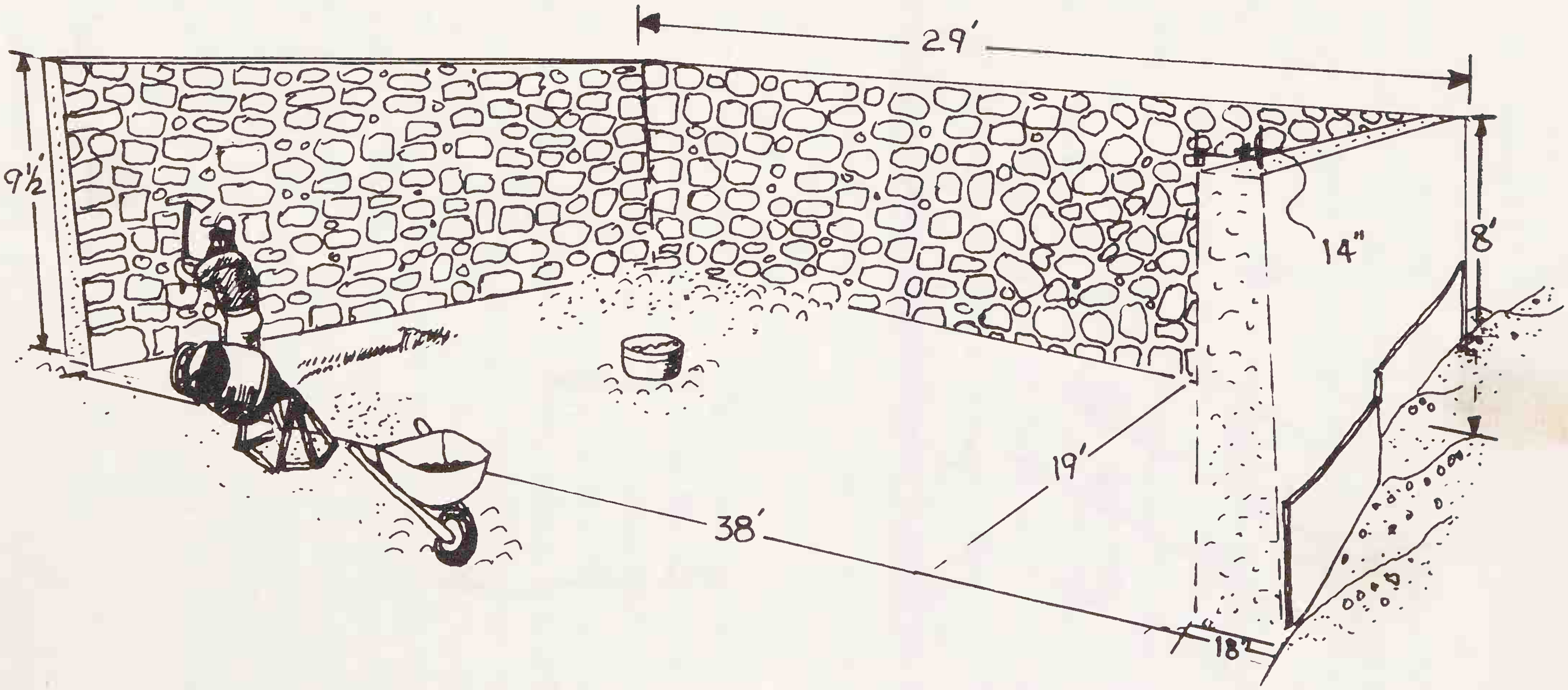


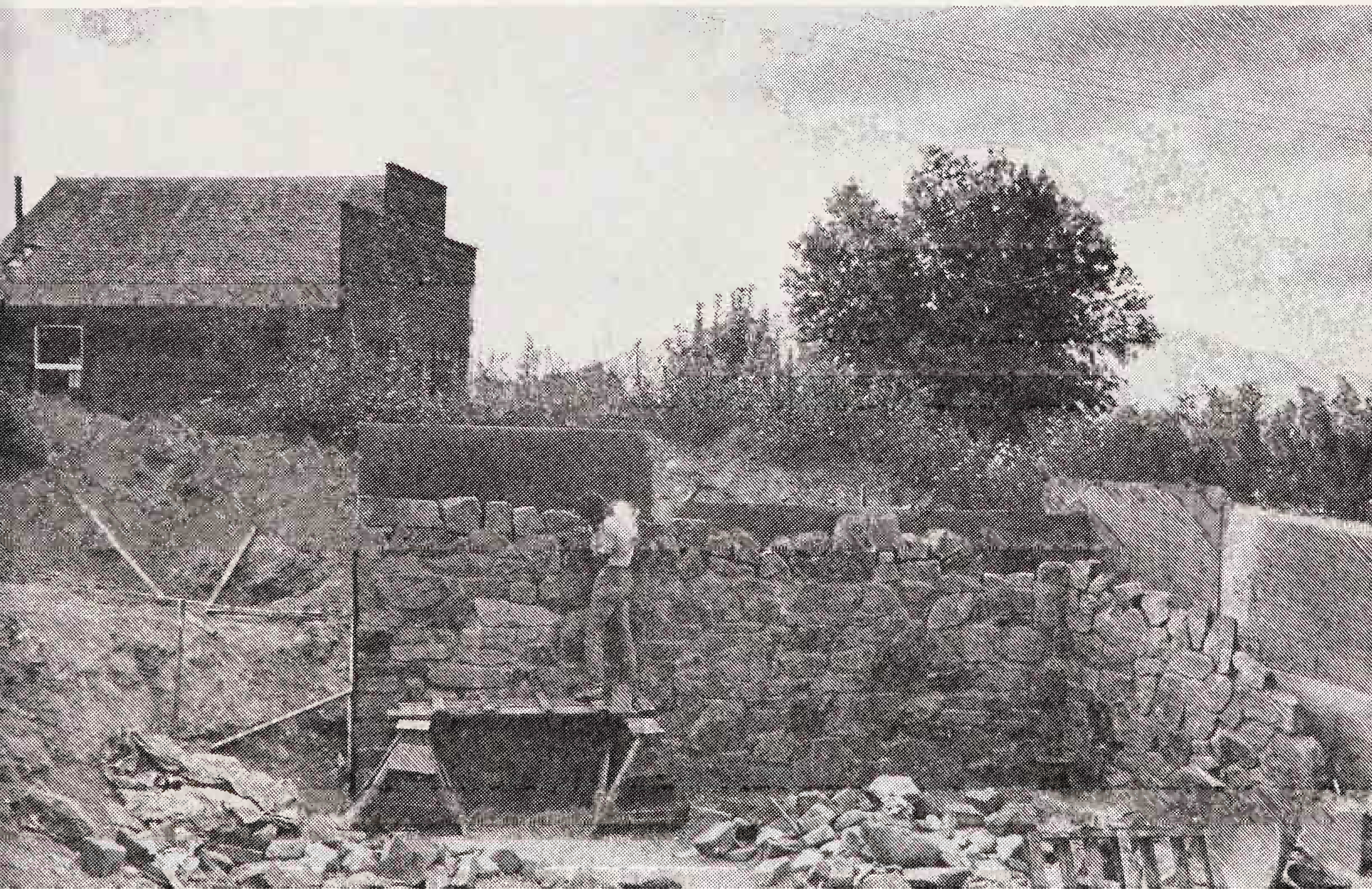
Figure 4-7 The work space dimensions for the Baty underground studio/workshop

a trapezoid measuring 38 feet in front, 29 feet in back, and has an overall depth of 19 feet enclosing approximately 640 square feet of workspace. Out-of-pocket costs were approximately $2500, or a little under $4 per square foot.

Doug saved money by digging his footings by hand. It was a full month and a half of hard pick and shovel work. "Would you do it again?" I asked. "Possibly not," he said, "but it was still a worthwhile 'one time' experience."

Once Doug had completed his two-foot-wide footing, he was ready to begin working on the wall itself. The workshop walls are 9½ feet high in the front and 8 feet high in the back—providing a "natural" slope of about one vertical inch to each linear foot for his underground roof. He first erected a temporary ¾ inch piece of plywood to form up the wall's outer surface. He then laid a row of stone "dry" in order to visualize the color and pattern arrangement and also to check the stone's fit. Here is one obvious advantage of *laying* stone as compared with Flagg's double form method. With open stone, an artistic eye can adjust here

Figure 4-8 Row upon row of stone is laid against a temporary ¾″ plywood backing. Using this method you can easily visualize the color and pattern of the stone.



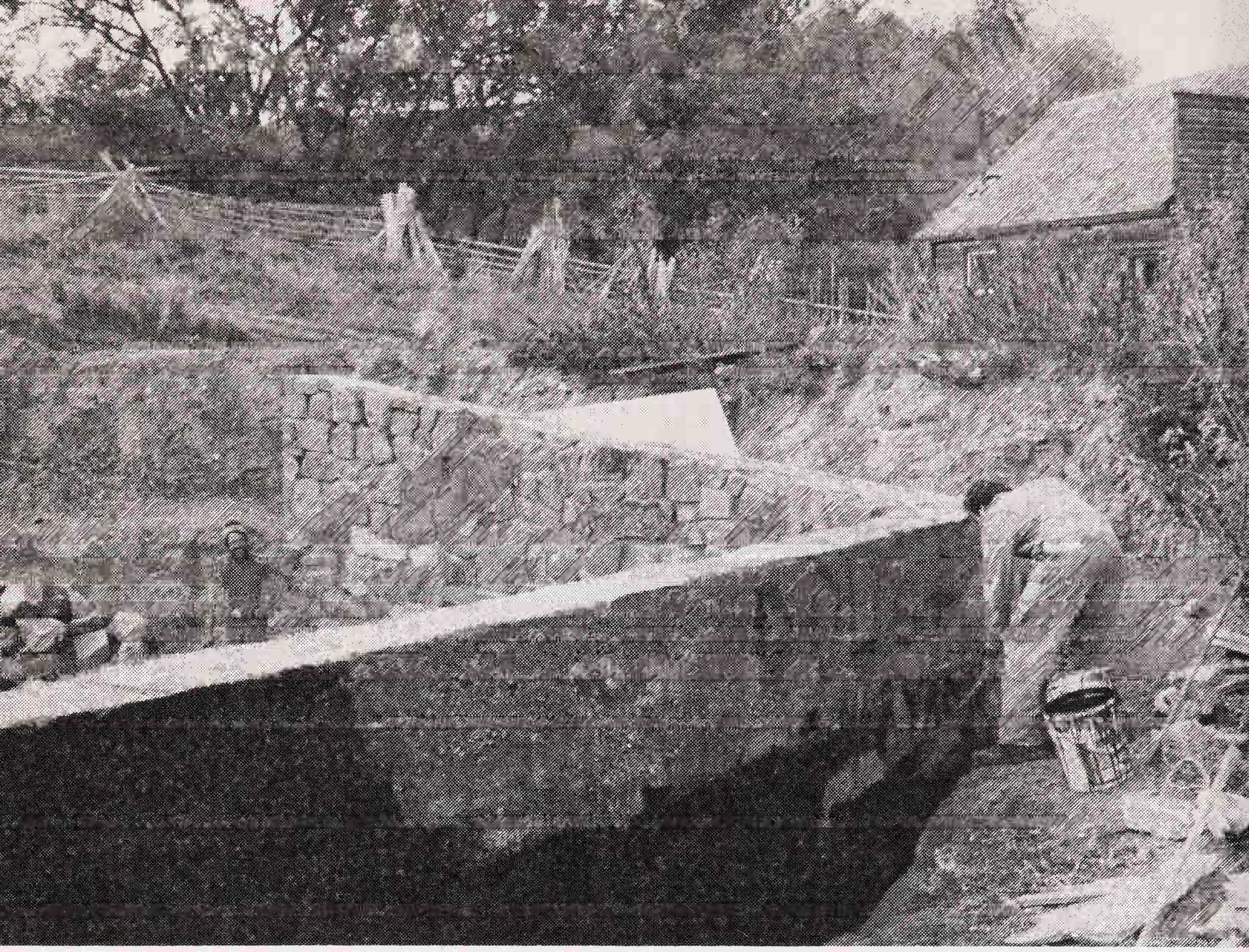
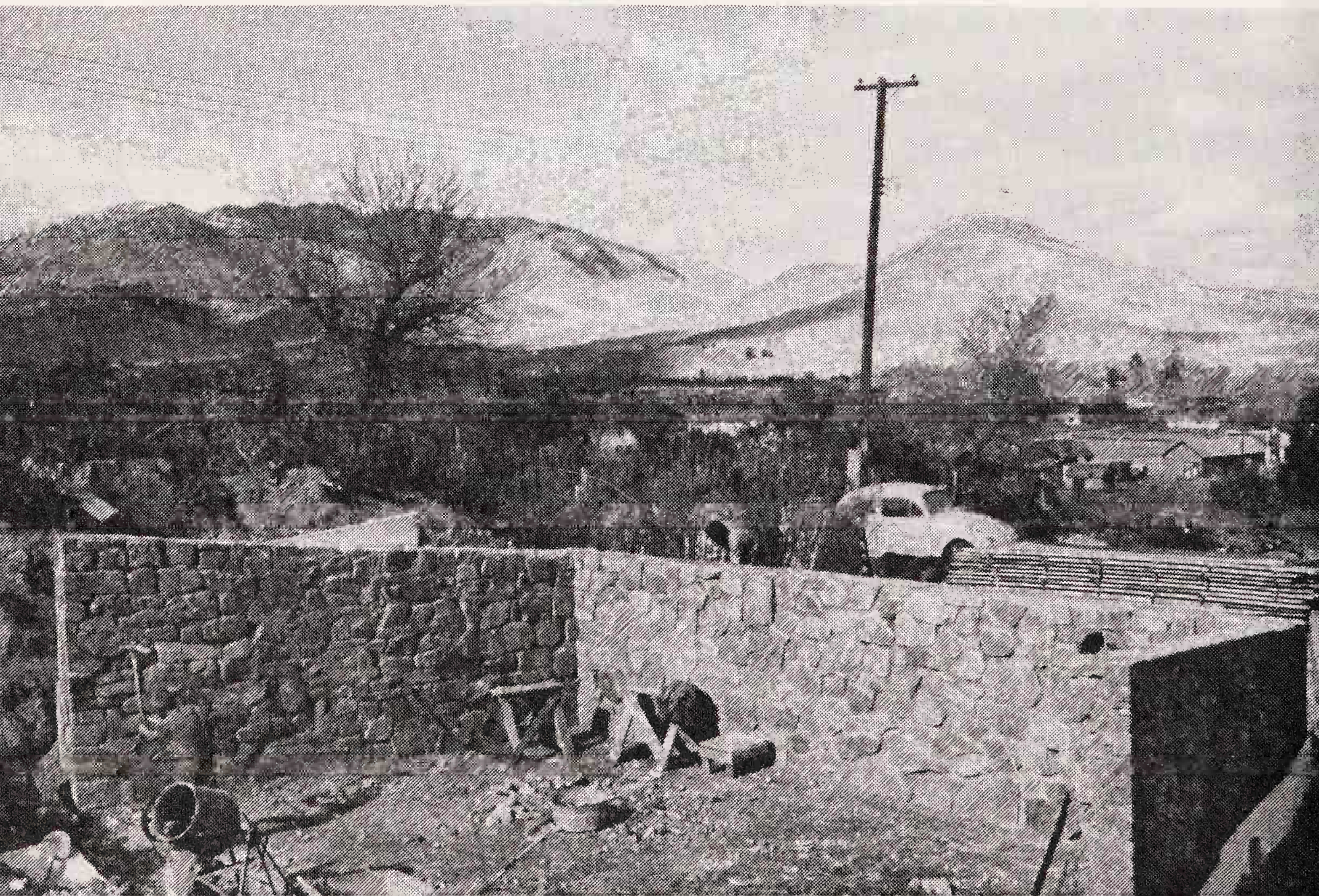


Figure 4-9 Asphalt mastic is applied against the exterior surface of the completed wall.

Figure 4-10 The completed wall is in the process of being damp-proofed and insulated. Note insulation on right exterior wall.

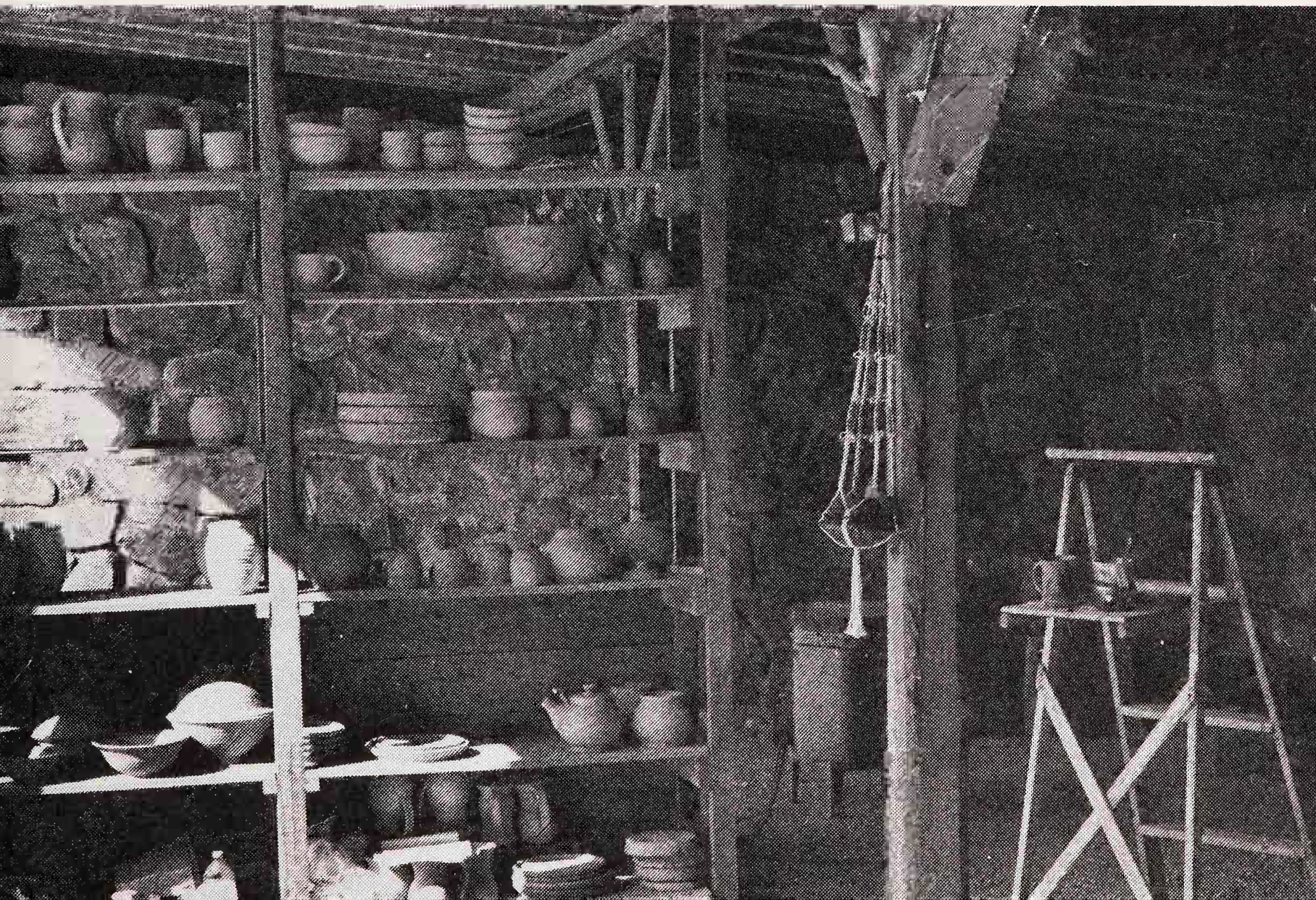


and there as well as substitute different shapes and colors until the most pleasing mosaic pattern is achieved.

Once Doug was satisfied with the arrangement, he set the stones permanently in mortar, allowing them to dry overnight. The next day he carefully filled concrete and rubble in between the stone and plywood form, tamping as he went to minimize air pockets. Steel rebar was placed at appropriate distances. The next row of face stones was begun immediately—repeating the sequence described above. Fig. 4-8 gives you a general idea of the process. When Doug reached the top of the form, he would simply tack on another plywood sheet—making sure it was braced securely. When the forms were removed (after the completion of a wall), he had a flat surface on which to apply asphalt mastic (fig. 4-9). The completed wall, partially damp-proofed and insulated, can be seen in fig. 4-10.

The workshop roof is supported by three 6×6 inch pine posts which, in turn, support a 6×6 inch fir beam (fig. 4-11). Above the

Figure 4-11 6″ × 6″ posts support a 6″ × 6″ beam which, in turn, supports the workshop roof.



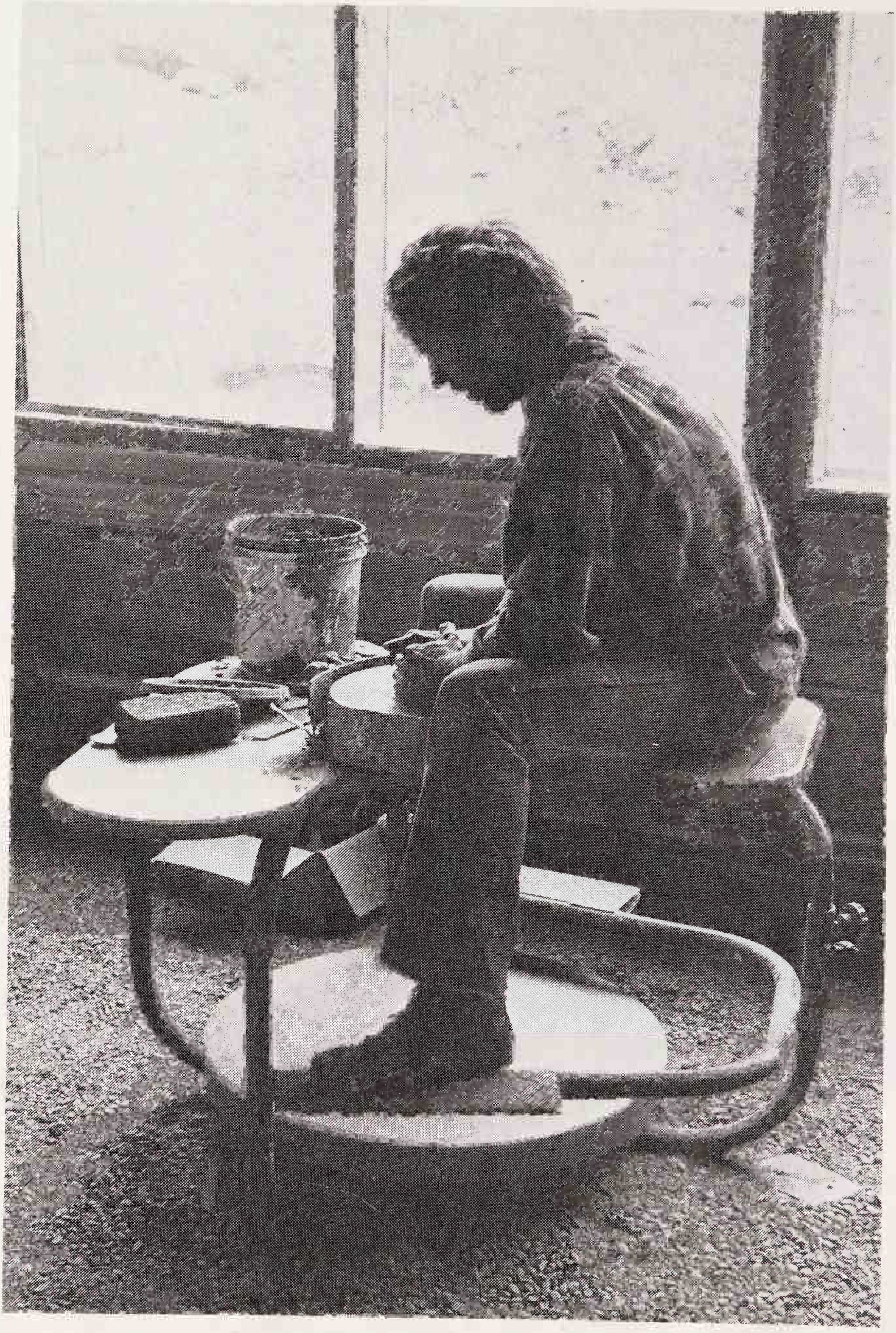


Figure 4-12 An inexpensive pea-gravel floor works out well for potter's studio/workshop.

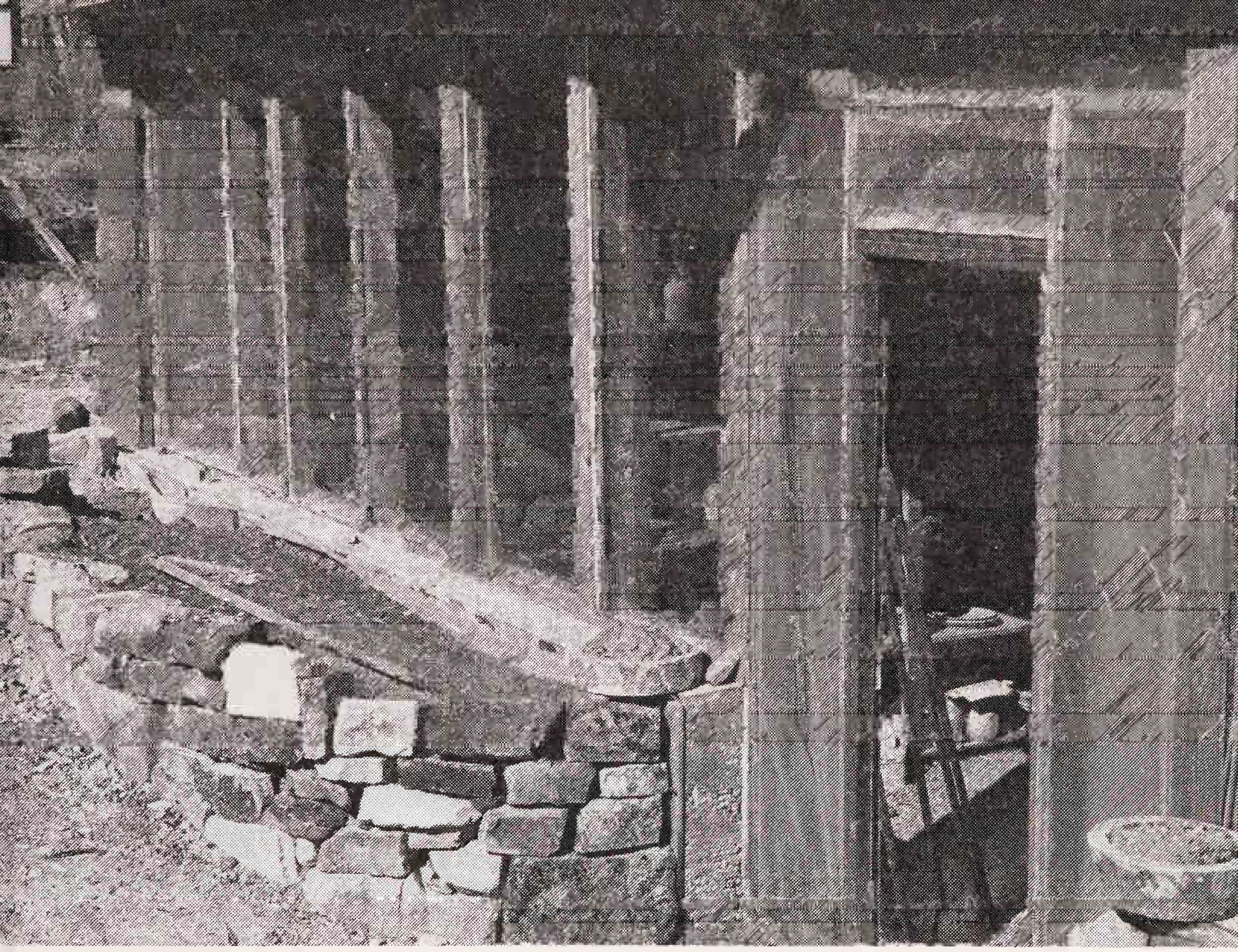


Figure 4-13 **The Baty studio/workshop: the south facing wall provides passive solar heat for cold winter days.**

beam are 3×6 inch rafters spaced sixteen inches apart. Moving up from the rafters (in sequence) we find: a) 1 inch planking, b) ¾ inch plywood, c) 30 lb. felt, d) 2 inches of polystyrene insulation, e) 6 mil plastic, f) 3 inches of dirt, g) another black plastic, and finally, h) 6 inches of wood chips. Wood chips are also used to berm up the workshop walls.

Thus far (after a year and a half of use), Doug reports that there have been no wall cracks nor any moisture leaks from either the roof or the walls. However, as in any new masonry interior, he does occasionally experience high humidity during certain times of the year. Doug plans to install an ''air-to-air Heat Exchanger,'' which will not only help lower the humidity, but will also keep his nearly ''air-tight'' studio ventilated through a transfer of heat from the relatively warm outgoing air to the cold incoming air.

A 6 inch pea-gravel floor worked out perfectly for Doug's pottery work (fig. 4-12). And the south facing wall (fig. 4-13) provides passive solar heating during those clear, cold winter days.

All in all, Doug's studio is an ideal workspace—bright, roomy, and comfortable. Like the other stone-builders discussed in this chapter, Baty felt that the months and months of hard work were well worth the effort.

In conclusion, this stone workshop represents but one more way to build with stone and also illustrates one more way a person with little experience can build an attractive low-cost earth shelter.

Chapter 5

Wood Foundations

> ''The carpenter dresses his plank, the tongue of his foreplane whistles its wild ascending lisp. . .''
>
> Walt Whitman

One of the things I look forward to in the summer is teaching a University of Wisconsin extension class called ''Owner-Built No-Mortgage Homes.'' One advantage of organizing a course like this is that it gives me an excuse to ''drop in'' on homesteads that look interesting from the low-cost, owner/builder viewpoint. Our class has visited remodeled houses, pole-houses, log-cabins, domes, homes made of second-hand brick and stone and finally, houses built with conventional stick or stud framework. More recently, we have been looking at some earth-sheltered homes.

The ''no-mortgage'' criteria I use in my class is a house built with a materials costs of $15,000 or less. Although no one has built a true underground ‘‘no-mortgage’’ house in our area, there are some examples of attractive and surprisingly inexpensive homes using earth-sheltered principles. Later on in this chapter, we will look at one such house built by Bob and Debbie Aaron—a house that incorporates a different approach to underground foundations. But first, some background.

Structural alternatives that we have mentioned thus far have been: a) pole foundation (Oehler), b) concrete block with surface bonding (Roy), c) stone (Nearing, Watson, Schwenke, Baty), and finally d) poured concrete reinforced wall. (Note: more discussion on this type of wall in chapters 6-11.)

Debbie and Bob Aaron have successfully used a fourth alternative—a wood foundation treated with chemical preservative. Actually, the treated wood basement has been around for over twenty years but has only gained popularity since the early 1970’s. In terms of material cost, these foundations are not significantly cheaper than concrete—but they nonetheless offer the owner/builder certain advantages.

For one thing, a wood foundation can easily be erected by the amateur owner/builder. Also wood foundations can be constructed in all seasons while building with concrete or stone is normally undertaken in the warmer months. Back-in-the-woods sites and generally inaccessible places may be entirely inappropriate for the earth-jarring, monstrous, ready-mix trucks. Here, ‘‘stick’’ construction (or blocks) may be the only practical alternative.

Another advantage is insulation. A treated wood foundation will usually have 2×6 or 2×8 studding which makes for ‘‘easy-to-apply’’ and inexpensive fiberglass insulation. Warmth and dryness are, in fact, the major advertised advantages of this kind of construction. In addition, the studding provides a convenient nailing surface for an interior wall covering—a definite advantage in finishing off the inside.

What about the drawbacks to the treated wood foundation? There are, I think, three potential problems: longevity, moisture infiltration and toxicity. Let’s begin with the question of longevity.

There has been extensive research on the expected life of treated wood implanted in the soil. Not too long ago, for example, the Forest Products Laboratory of Madison, Wisconsin pulled up a number of 2×4's that had been in the ground at a test site in Mississippi. After twenty-five years, these creosoted stakes showed no appreciable deterioration. Telephone poles (again, pressure-treated with creosote) have been in the ground in our area since the late 1930's and show very little; if any, decay or rotting. Based on these observations, one could safely say that the treated members of a wood foundation could be expected to have a life of forty years plus. Yet, a forty-to-fifty-year figure might give one pause when put into the context of the payback period of a normal home mortgage.

Much, of course, depends on soil type, drainage conditions, and water-proofing efficiency. For example, the average fifty year life would probably be increased if you were building in sandy or gravel soils. Second best would be sand-clay and sandy-loam. Least desirable and *not* recommended for this type of foundation are the heavy clay, fine silt, and peat soils.

A good drainage system at the base of your foundation is always advisable no matter what type of soil you have. The National Forest Products Association, a trade group that helped develop the "all weather basement," recommends what they call a "dry basement design."

This design specifies using a four inch underlayment of pea gravel or crushed stone and a 24 inch by 30 inch deep precast concrete tile sump under the slab. The sump, in turn, is designed to drain into a sewer or the open air. For more details, see the Association's book: *All-Weather Wood Foundation System-Design, Fabrication, Installation Manual.* (Appendix 1)

Moistureproofing

Unfortunately good drainage will not prevent all moisture problems. Particularly if you build into a hill, you may get a temporary buildup of water pressure during heavy rains. To prevent water infiltration, you will need some kind of moistureproofing system for your walls.

The industry's solution to this problem is to waterproof the plywood outer wall by first caulking the seams and then applying an asphalt mastic coating to the plywood surface. While the asphalt is still tacky, you implant a sheet of 6 mil polyethelyne into the mastic.

However a problem may arise with this technique if there is any tear, cut, or other perforation in the plastic membrane. After even the most careful backfilling operation, it would not be surprising to find a small puncture. Other long-term considerations would include destruction from the rodents seeking heat, food, or nesting material, as well as ordinary, long-run deterioration of the plastic itself.

And if there are any tears in the membrane, you can be sure that moisture *will* come through. If this becomes a chronic problem, the life of the foundation could be adversely affected, and in addition, any moisture infiltration into the fiberglass would greatly reduce its insulating effectiveness.

Also unanswered is the question of the longevity of the caulking and of the construction adhesive used to seal the plastic at the lap joints. One contractor in our area uses butyl caulk for the plywood joints and an asphalt sealent for lapping the plastic. In subterranean conditions, these sealants would probably have a normal life of only six to ten years.

I'm going into all these sealing details simply because they do call into question the long-term effectiveness of the conventional moistureproofing techniques. I would think that the owner/builder who wants a treated wood foundation can do better on his or her own. Later in this chapter, we will take a close look at a more thorough method of waterproofing when we examine the Aaron home.

Toxicity

Fortunately no one advocates using oil borne preservatives such as creosote and pentachlorophenol (penta). These are not only the most toxic chemicals used in wood preservation, but they also have an odor that disqualifies them for home wood foundations.

The other choices are the water borne salts such as Chromated Copper Arsenate (CCA), Ammonical Copper Arsenate (ACA), etc. These chemicals do not have an offensive odor and at the same time they are considered (by the industry) as completely safe for treated wood used in habitable dwellings.

Recently, however, there have been some concerns raised because of the arsenic component of these preservatives. For one thing, there may be some leaching of the chemical—especially if moisture seeps through the wood. And if there is a leaching problem, it will not only get into the ground (which is a problem of its own), but could conceivably get into the living area. Extreme care in installing a continuous plastic vapor barrier next to the interior side of the insulation ought to minimize this problem.

What the industry does not seem to have addressed however, is the problem of fire, where tremendous amounts of arsenic would be released upon combustion of the treated wood. Tests done by Tod Torgerson at the University of Wisconsin-Stout indicated that wood treated with Copper Chromated Arsenate is slightly *more* inflammable than non-treated wood. This hazard is magnified somewhat when we consider that a wood foundation for an underground house encompasses the *main* living area instead of the usually less-occupied basement.

But again, it is possible to take precautions by using, say, ⅝ inch sheet-rock for your interior wall covering, and by installing smoke detectors throughout the house. I shudder to think of all the families who attempt to save money and effort by using low-cost inflammable coverings such as 3⁄16 inch paneling. On the back of one company's advertising pamphlet called "Why Buy a Menard Treated Wood Foundation?" there's a drawing of a happy family playing together in a treated wood basement in which paneling is clearly used as a wall covering!

Considering the potential problems, should you use a treated

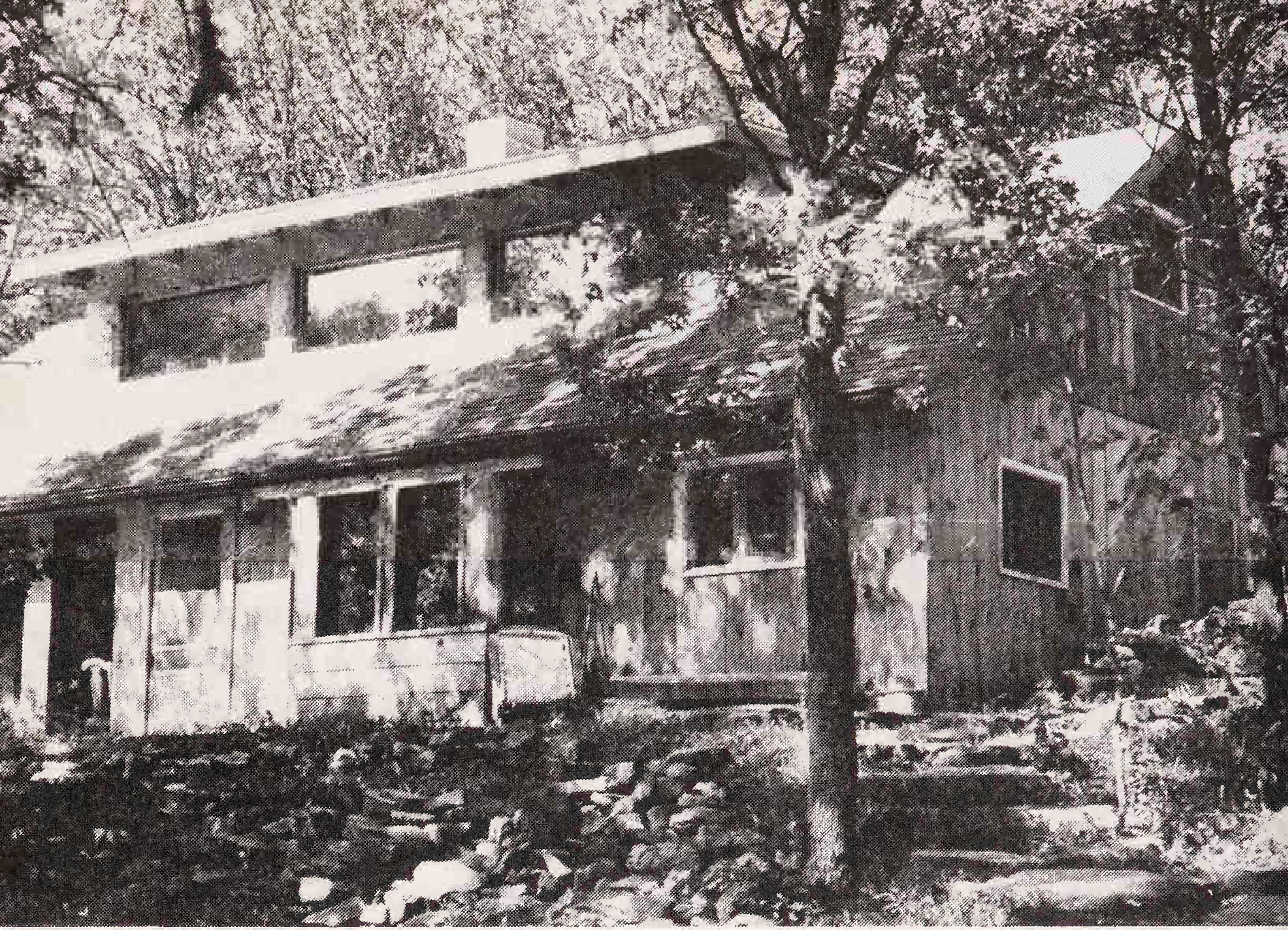


Figure 5-1 The Aaron house (for $11,000 or $11 a square foot), is a good example of a low-cost earth shelter.

wood system? Again it is up to you. These foundations do have some definite advantages, and most of their serious drawbacks I think can be overcome by using quality materials and extreme care in building. My own preference is still stone, poured concrete or the surface-bonded method mentioned earlier. Concrete or stone walls will last and last, they're fireproof and finally, they're able to store heat for passive solar energy.

But assuming that you are still interested in the wood foundation, you might find it worthwhile to examine the experiences of Bob and Debbie Aaron who have used this method with apparent success, and at the same time, have kept well within our low cost guidelines.

The Aaron Home

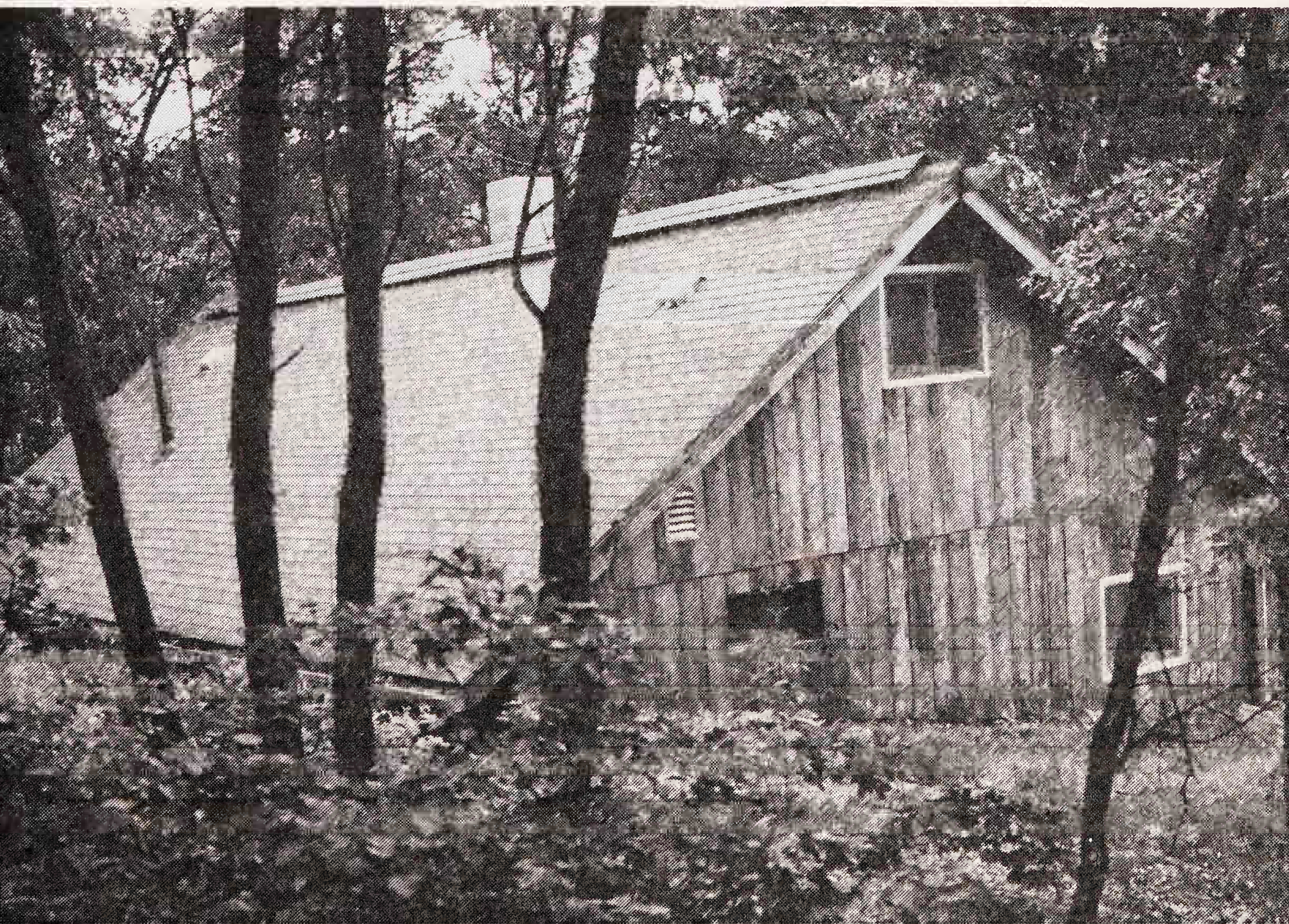
The Aaron house, located in the rolling hills of west-central

Wisconsin, is an excellent example of what an owner/builder can do with a little over eleven thousand dollars (not including the cost of the well), or about eleven dollars per square foot. This is about a third of what a conventional home costs.

Of course Bob Aaron spent an entire summer building and his labor is not included in the overall cost figure. Yet their house was built without incurring a large amount of debt. Besides a relatively small bank loan, most of the working capital came from the sale of a parcel of land from the Aaron's original eighty acres.

Their costs were also minimized by a) ordering rough-cut studding and planking from a local sawmill, b) taking advantage of a sale on treated plywood, and finally, c) obtaining help with his concrete work from friends. Actual construction began in May 1979, and Debbie and Bob were able to move out of their small trailer into their semi-finished house by September of the same year.

Figure 5-2 The Aaron home demonstrates good utilization of earth-sheltered principles on the entire back (north) wall and the side walls as well.



And a handsome house it is. Aaron built into a south-facing hill and used earth covering for the complete forty-foot long north side, and part of the east and west sides.

There is an upstairs living area heated partly by sunlight radiating through three large thermopanes in the southfacing dormer. Eight thermopanes in the bottom story plus other windows, including two small ones on top of the upper north wall, add extra light and ventilation. Contributing to the visual attractiveness of the home is rough-cut pine siding and a wood deck in front.

Normally a contractor will build a treated wood foundation on a gravel footing and then add a concrete slab afterwards. Bob poured his concrete first. His footing, poured at the same time as the four-inch floor, is a foot deep and a foot wide. It contains 8-inch-diameter concrete piers every four feet both in the front of the building and continuing eight feet into the sides. The piers, which are designed to prevent frost heaving, go down about four feet.

When the slab-footing was cured, Bob built up his east, west, and north walls from a treated wood plate glued and bolted onto the footing. These bolts, embedded into the concrete, were placed four feet apart.

Framing consists of non-treated 2×6 studs on 16 inch centers. [A number of builders and architects recommend going with 2×8 studs on 12 inch centers when building into a hill.] There is additional wall bracing capacity from three interior walls that run perpendicular to the back wall. The outer wall itself is ⅝ inch treated plywood. At this point we should caution anyone who plans to build with treated wood *not* to use regular steel nails. Why not? It's because the acids in the chemically treated wood will tend to corrode regular fasteners. Most sources recommend nails made of stainless steel, bronze-copper, or hot-dipped zinc.

In waterproofing his earth-covered walls, Bob was both careful and thorough. Knowing that there may be considerable water buildup from the hill, he decided to put in two 4 inch plastic drain tiles which he covered with gravel. On his earthern wall sections, he caulked all the seams with buytl caulk and troweled on a layer

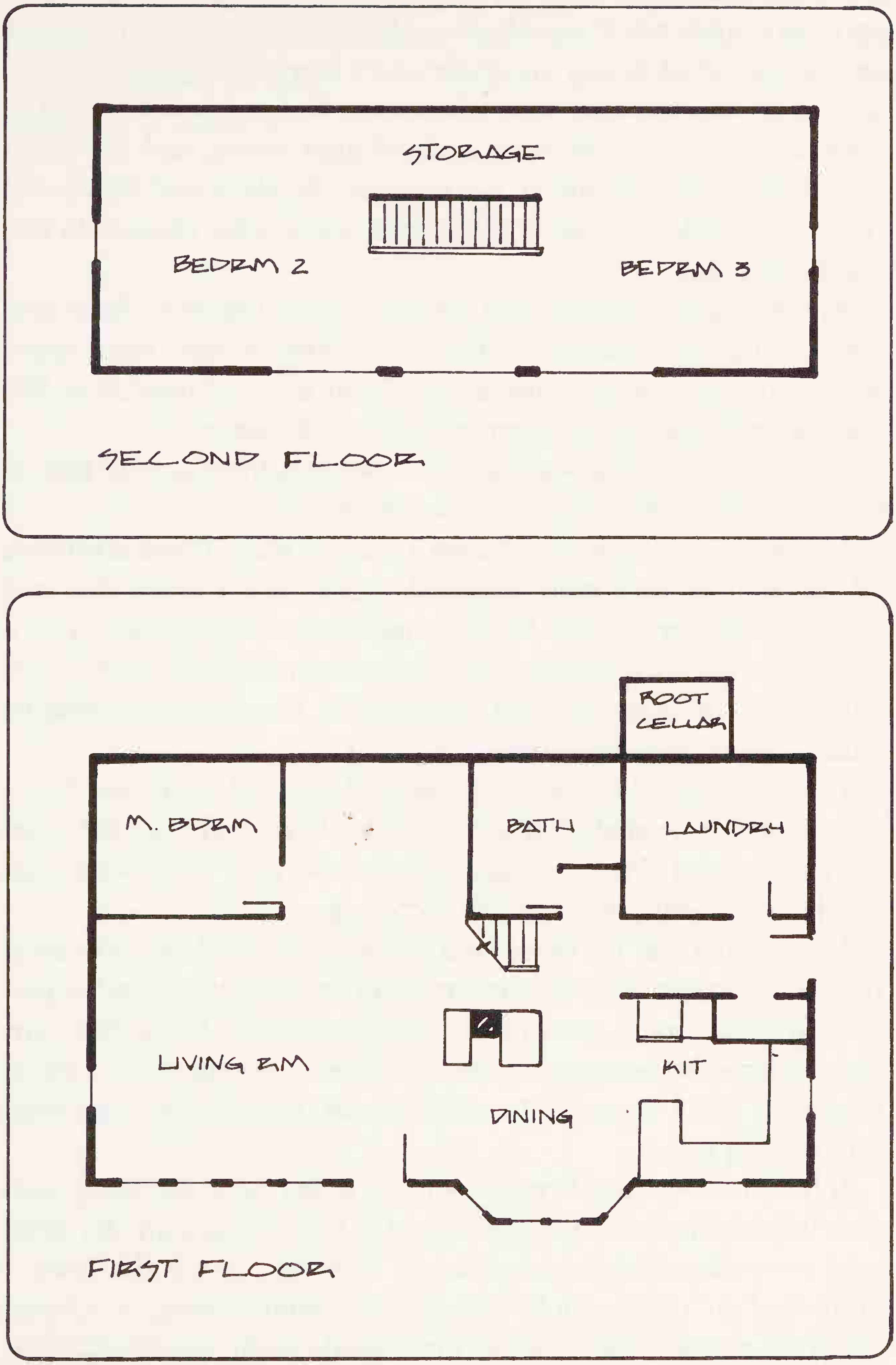


Figure 5-3 The Aaron house floor plan.

of plastic cement. While the mastic was still sticky, he pressed on a layer of 6 mil black plastic. After this was dry, Bob added an extra layer of heavy roll roofing half lapped. Expensive? Yes, and extra trouble too—but remember that these earth-packed walls are the most vulnerable areas of your house, and any moisture infiltration here might not only accelerate wood decay and ruin your insulation, but it might also leach toxic chemicals into the living area.

Another interesting aspect of the Aaron house is their root cellar, built into the hill on the north side—a dark, cool space with a constant earth temperature. Other areas of interest in this particular house can be seen in the overall floor plan.

Another interesting feature of this home is their second exit on the east end of the house, as seen in fig. 5-2.

In summary, I found the Aaron's treated wood home attractive on the outside and quite pleasant inside; it's a place that will undoubtedly serve their family's needs for many, many years. And from our own perspective, their house illustrates one more alternative of how one can construct a low-cost, low-maintenance, earth-sheltered home.

Let's assume that you have decided to build a modest house or another earth-sheltered project. You have saved up sufficient working capital. You have also decided on your foundation type and have carefully worked out the design.

Meanwhile you've been squirreling away building materials from salvage operations, auctions, and special sales. You've purchased or borrowed most of the necessary tools. And finally, you have made arrangments to be free from non-building commitments for a full summer. In other words, you're eager to plunge into the big job.

But wait a second. Perhaps you've never done anything quite like this before . . . and you're just a little bit scared. So while you are waiting for the weather to clear up, or for the frost to come out of the ground, perhaps we should spend a moment discussing what you can expect in regards to the upcoming work.

This will be a job that will tax your muscle power, your reasoning power, and your patience. Can you do it? Will you survive? What's exactly in store for you? Let's now take a look as we move on to chapter 6.

Chapter 6

Work

> "We go forward without facts and we learn the facts as we go along."
>
> Henry Ford

Good work.

For a long time now I have been a great admirer of Helen and Scott Nearing. Part of what attracts me to their way of living is how they organize and undertake their work. Everything seems slow-paced, well-planned, and deliberate—whether taking twenty years to build up a homestead in Vermont or fourteen years to build a stone wall around their large garden in Maine.

Their final results are indeed beautiful, artifacts that speak of craftsmanship and care. Yet it is their *work process* itself that seems even more admirable to me. It has an almost timeless quality about it.

In a similar vein, I am reminded of Robert Pirsig's description of how he adjusts an engine tappet from his book, *Zen and the Art of Motorcycle Maintenance:*

> The first tappet is right on, no adjustment required, so I move on to the next . . . I always feel like I'm in church when I do this . . . The gage is some kind of religious icon and I'm performing a holy rite with it.[16]

Indeed, who does not envy this frame of mind, this quiet interplay between absorbtion and detachment; who would not wish to duplicate this experience?

Yet contrast Pirsig's or the Nearings's approach to work with Mike Oehler's description of how he gets going on those tough construction jobs:

> . . . put off that tough part that has you stymied till last. Then, finally, when there is nothing else that can be done and the whole project is being held up due to lack of completion of that critical section . . . spend a day or two going swimming, fishing, etc. This serves several purposes; (1) it makes you regret "wasting" the time and (2) it allows your mind to fester.
>
> Once you begin to worry about letting time slip through your fingers, you'll get desperate to finish the job. You'll be infused with a form of cheap courage which should give you enough motivation to actually tackle that seemingly impossible task.[17]

We might as well reveal the truth right now. Mike's description of the mental festering and the energetic nervousness is, unfortunately, closer to what you can expect than the slow deliberation of the Nearings or the serene sanctuary experience of Bob Persig's motorcycle tune-up.

This will be especially true if you are inexperienced, as any brand new work experience is bound to be anxiety producing.

And when you combine this mental stress with the inevitable physical strain, you have a situation where the body/mind capabilities are stretched to their limit—quite possibly for the first time in your life.

Some builders I've known feel this stress factor so much that they prefer to do most of the construction work alone—at their *own* pace—even though at times friends or partners could be extremely helpful.

Another factor in the desire to work alone is that it can take some of the pressure off making mistakes—and you will undoubtedly be making plenty of them. Some of your mistakes will be due to the fact that modern underground housing is a new and untested idea. In this sense, we're all explorers forging ahead into new territory, and even the best builders are bound to make errors in some phase of construction.

But the majority of your mistakes will take the form of doing things incorrectly during the day-to-day construction grind. I made so many of these kinds of errors that I had a special space on the bottom of each page of my building journal called ''Mistakes of the Day.'' But why so many?

Mistakes are obviously made because of inexperience and, as Henry Ford observed, we're often forced to begin working without knowing all the facts of the situation. We also make mistakes because of the anxiety factor that we mentioned earlier. As you charge ahead, your mind's set into an inflexible groove; you tend to become blinded to the total consequences of what you are doing. Sooner or later, you begin to realize that something's wrong.

At this point, let me advise you *not* to get angry with yourself. Instead, see your problem more as the result of the pressures and newness of the situation rather than your own stupidity. In addition to expecting mistakes, attempt to see them as learning experiences. Correct what you can, tear out, and redo. And then go on. I think that I can honestly say that of the many building mistakes my wife and I have made over the years, they have all faded into insignificance as the total project moved ahead.

Yet there are ways, perhaps, to minimize these mistakes. One method is to discuss your design and specific building techniques with as many people as you can. Often they will see some incredibly obvious defect in your thinking—some consequence not recognized in your frenzy to get going. But beware! Anyone offering the builder advice must be extremely tactful in his or her comments and criticisms. Partners especially should remember not to get too personal. No recriminations, no "I told you so's." All too often I have seen in such interchange fertile ground for family arguments and bad feelings.

Also, there is no substitute for reading. There are many publications—many of them are free (trade association, government, etc.) and some of them may cost a few dollars. I have listed some of these building references in Appendix 1.

And finally, I've avoided some mistakes by thinking about the impending project right before I go to bed . . . or sometimes I force myself to sit down immediately before I begin working and spend a minimum of five quiet minutes considering the task before me, carefully thinking about what I'm trying to do and how I'll go about doing it. "Hmmm, do I have the tools, the necessary materials . . . perhaps I'd better recheck the cement/gravel proportion . . . . are there any splits in these roof rafters? . . . what's going to happen if it rains?" and so on.

One of the strangest problems I have encountered related to stress and mistakes is the inevitable visit from the inquisitive neighbor, friend, or relative.

There seem to be some mischievous spirit that sends this visitor over at the worst possible moment—a time when you've been trying to do something brand new, when you're unusually anxious and physically exhausted . . . and finally, when you've suddenly realized that something's wrong and it will have to be done over.

At this point, what happens? Of course, your visitor stops by. It'll probably be a person who has always been friendly with you, never any hassles. But that mischievous spirit got to him today, and he not only seems to take a subtle delight in your current mistake, but he also feels the need to tell you that your whole building concept is quite defective. With a never-before-heard hostility in his voice, he takes a half hour to explain why you're nuts to go earth-sheltered.

He's wedged that critique into your day with absolutely perfect timing. Now that invisible spirit is sitting there comfortably on the dirt, smiling away—waiting to see how you react. Of course, you do the only thing you can do . . . offer your visitor some tea and talk about gardening.

For a long time I thought I was the only one who encountered this "curious/hostile" visitor syndrome. But then I began talking to other owner/builders, and sure enough, that same spirit has been hard at work elsewhere. I enjoyed reading, for example, Ray Scott's similar frustrations in his book, *How to Build Your Own Underground Home:*

> So now you can just imagine the kick-in-the-head when some stranger (or friend) comes along and verbally tears your plans apart with inaccurate and incomplete knowledge or facts, after you have been working all weekend, or a distant relative drops in after a hard day's work and proceeds to tell you that you have a screw loose and probably means it. This is an example of the mental harassment you must be prepared to handle. Sometimes people can unintentionally be downright demoralizing.[18]

Again, your best defense against this kind of thing is to *expect* it. And when you see your visitor walking or driving in, realize that this trouble-making spirit is probably next to him goading him on.

Perhaps after reading these comments you may come to the sad conclusion that this kind of hassle isn't worth it. Indeed, there are bound to be some couples or families who are better off not attempting a large and complicated building project.

But from my own observations, common everyday individuals who go ahead and plunge into their construction projects find themselves pleased at their progress as the weeks roll by. Their secret I think is to take one little step at a time. They avoid thinking too often about the entire project, and they shun heavy-duty deadlines. Like the Danish fur trapper's principle, they know "the next mile is the only one a person really has to make."

The Nearings once said quite correctly that no job is really too big, "if you have a general idea of what you are about, break the project into manageable units, put through these units one at a time and have the thrill of fitting them into the overall pattern."[19]

And despite the neighbors who don't seem to understand, despite the many mistakes, the physical exhaustion, the dogged details that take three times as long as you had thought, the time-consuming trips back to the building supply store—and so on. Despite these negatives, you *will* begin to see some progress over the weeks and months.

And it is *your* accomplishment, by George, you own creation! And, of course, if you are building a house, the ultimate payoff is an energy efficient, low-overhead, "mortgage-free" place to live—a home whose long-run advantages can now be translated into greater freedom to do the things you *really* want to do, enlarging your options for your time and money, as well as your work and leisure.

And as you apply your skills and energy to the project, self-confidence increases and anxiety declines. Sooner or later you *will* find yourself doing some of those jobs with the quality of work that we discussed earlier—that slow, deliberate pace that can make construction so absorbing and satisfying. And finally, at some time in the future, perhaps—just perhaps—that inquisitive neighbor or relative may pay you another visit; only this time there is a measure of respect in his voice as he says, "hmmmm, not bad, not bad."

A Brief Look Ahead

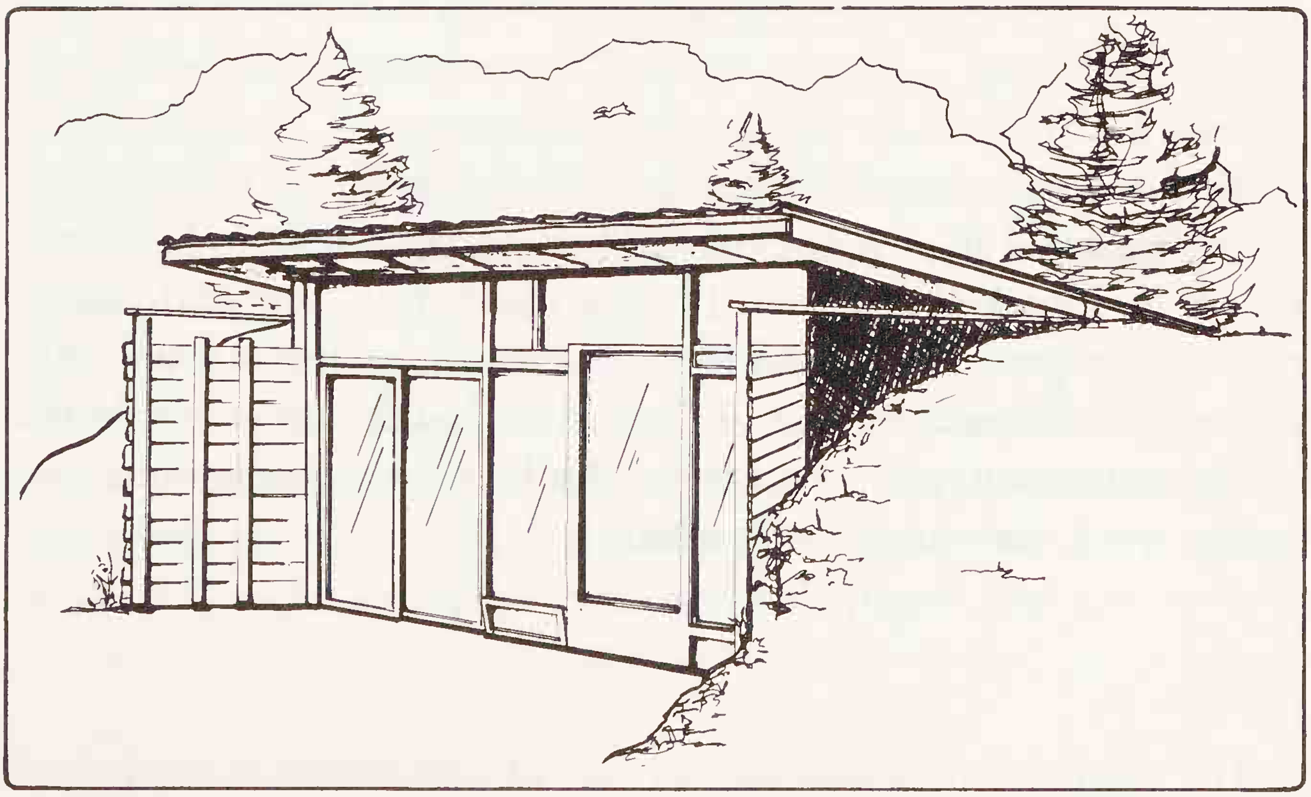
We're now ready to move from the general to the specific, from the theoretical to the actual. The next five chapters will be entirely devoted to narrating my own experiences in building a small, passive-solar, earth-sheltered structure during the summer of 1979.

It's a living space of extremely simple design and thus, one of the *least* expensive methods using a poured concrete foundation. As you read through this narrative, I hope that you will get even *more* of a "feel" for the nature of do-it-yourself construction—both the undeniable pleasures, as well as the inevitable frustrations. In addition, you should (hopefully) glean some further ideas on building details and methods that you may want to incorporate into your own earth-sheltered project.

Part II

BUILDING AN EARTH SHELTER

Well-roofed and pleasant is my little hut, And screened from winds:—Rain at thy will, thou god! My heart is well composed, my heart is free, And ardent is my mood. . .
Buddhist Songs of the Wayfarers



Chapter 7

Design

"Simplify, simplify. . ."

Henry Thoreau

I love to work in my little office.

Having used it now for four full seasons, I believe I can say that it has worked out well. It's not eleaborate, nor particularly pretty, yet the building has been comfortable, durable, and surprisingly efficient. Indeed, if I were to build a low-cost house using earth-sheltered principles, I doubt if it would be much different from the one described below.

Design

The structure is essentially a 10 × 15 foot concrete room, half in the ground, half out. There is no hill, in fact nothing really special about the site. Only an unobstructed southern exposure. The dirt that was excavated from the hole and from the front was used to berm the three poured walls on the north, east, and west sides.

The south wall is ‘‘open’’—or more accurately, it is almost all glass, having nearly eighty square feet of thermopane window. The building has a concrete floor painted flat black. The concrete walls and floor are insulated on the *outside*, making the structure function as a large heat storage container. And sure enough, on those cold days in January and February, when the sun rises low in a clear sky, there is no need for any supplementary wood heat until long after dark. The earth-berm effectively blocks wind infiltration and delivers a constant earth heat to the walls throughout the winter. And in the summer, the concrete adjacent to the cool earth helps keep the interior relatively cool as well.

After reviewing the pros and cons of whether to go ‘‘true’’ underground or not, I decided against using a earthen roof because of its additional cost and also because of the relative simplicity of building and waterproofing a conventional roof. What I have is an ordinary shedroof with a slope of two inches to every linear foot (a ‘‘2 to 12’’ pitch). There are six inches of insulation in the ceiling, an air space above, and galvanized steel roofing on top.* The completed structure (without electricity or plumbing) cost a little less than fifteen dollars per square foot in 1979 prices. A larger structure would not have proportionately larger excavating costs, and hence would be slightly cheaper on a square footage basis.

For the workshop walls, I used reinforced concrete mainly because its overall cost ($645) was within my overall construction budget. There was also the advantage of speed; I can fondly recall that bright sunny day when a friend and I sat on top of one of the large excavated sand piles and watched a three man crew set up the wall forms in the morning. By midafternoon, the ready-mix truck had finished pouring, and two days later I could begin working on the roof.

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*For a house, I would double the ceiling insulation to 12 inches (R-38).

Thermal Considerations

When you insulate the *outside* of concrete or block walls, recall that the recommended insulation was "extruded" or "closed-cell" polystyrene. The resistance factor of this material ranges from R4 to R5 per inch depending on who manufacturers it and the temperature of the earth. Remember not to confuse this product with the more common "bead-board." Bead-board's much less costly, but unfortunately it absorbs water and will disintegrate if exposed to moisture for a prolonged period of time.

I had planned to use four inches of insulation on my walls (as recommended by the Underground Space Center). But when I found out that a 1 inch sheet cost about nine dollars, I decided to compromise by using 3 inches on the top two feet, 2 inches on the next two feet, and 1 inch on the bottom four feet of my eight foot wall. In addition, I put 1 inch under the floor to minimize solar heat loss and to prevent condensation during those extra humid days in the summer.

Also, as we mentioned earlier, it's advisable to install an overhang on the front (south) side to block out unwanted solar heat during the warmest months. The overhang for my office is thirty two inches; and at a height of about ten feet, it will allow only a couple of inches of summer sun into the room.

Yet there are times—sunny days in the spring and fall—when it can get uncomfortably hot. Remember that there's nearly eighty square feet of glass for my relatively small 150 square foot floor—a ratio that's great in the winter, but may present a problem during other seasons. To block solar heat when it's unwelcome, I use portable insulated panels.

A single panel consists of a 4 × 8 foot sheet of bead-board sandwiched between thin particle board and a sheet of inexpensive paneling. Total material cost for the four panels was approximately forty dollars. To make a single panel, I first glued the 4 × 8

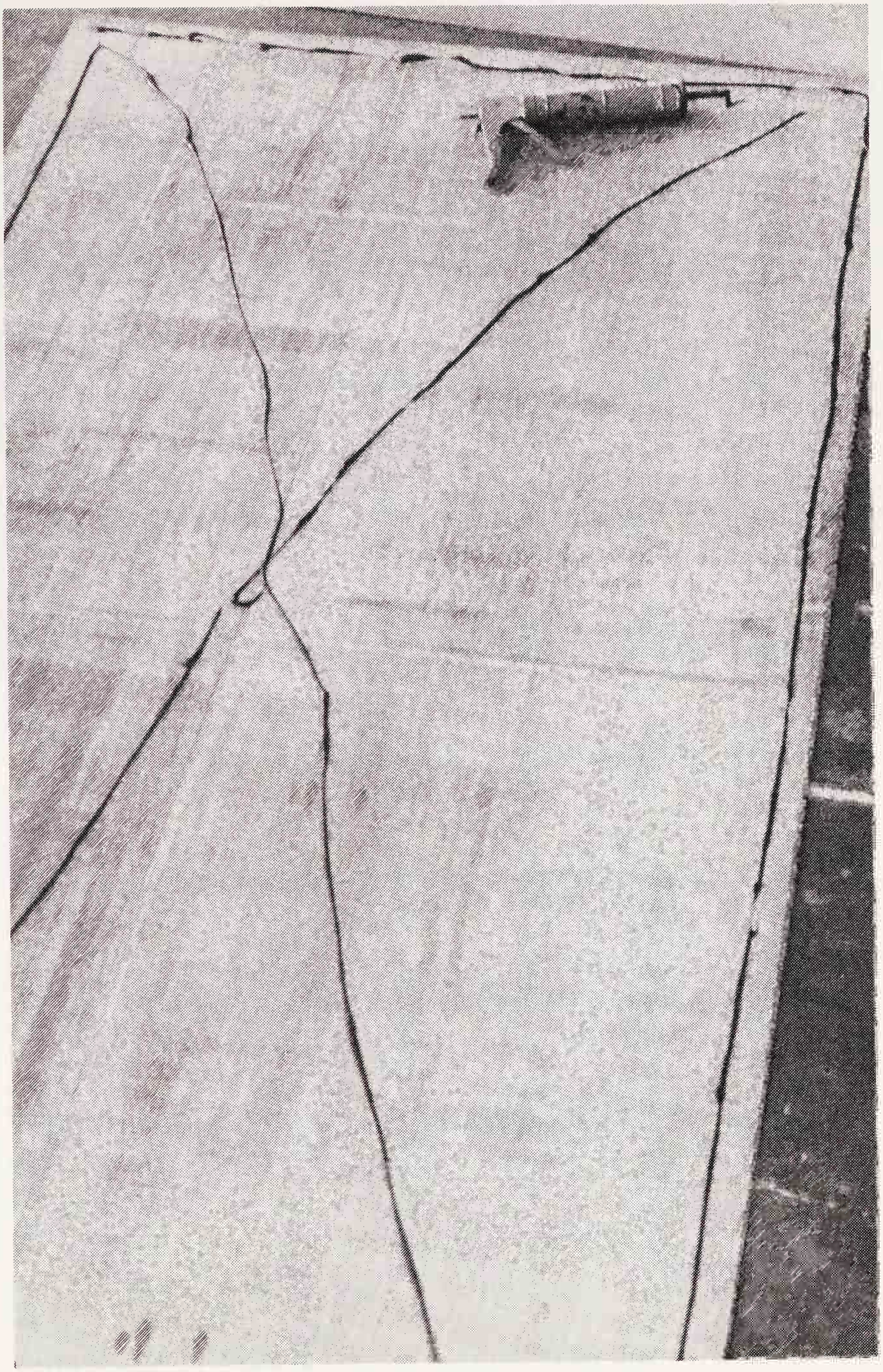

Figure 7-1 First step in making the insulated panels—applying glue.

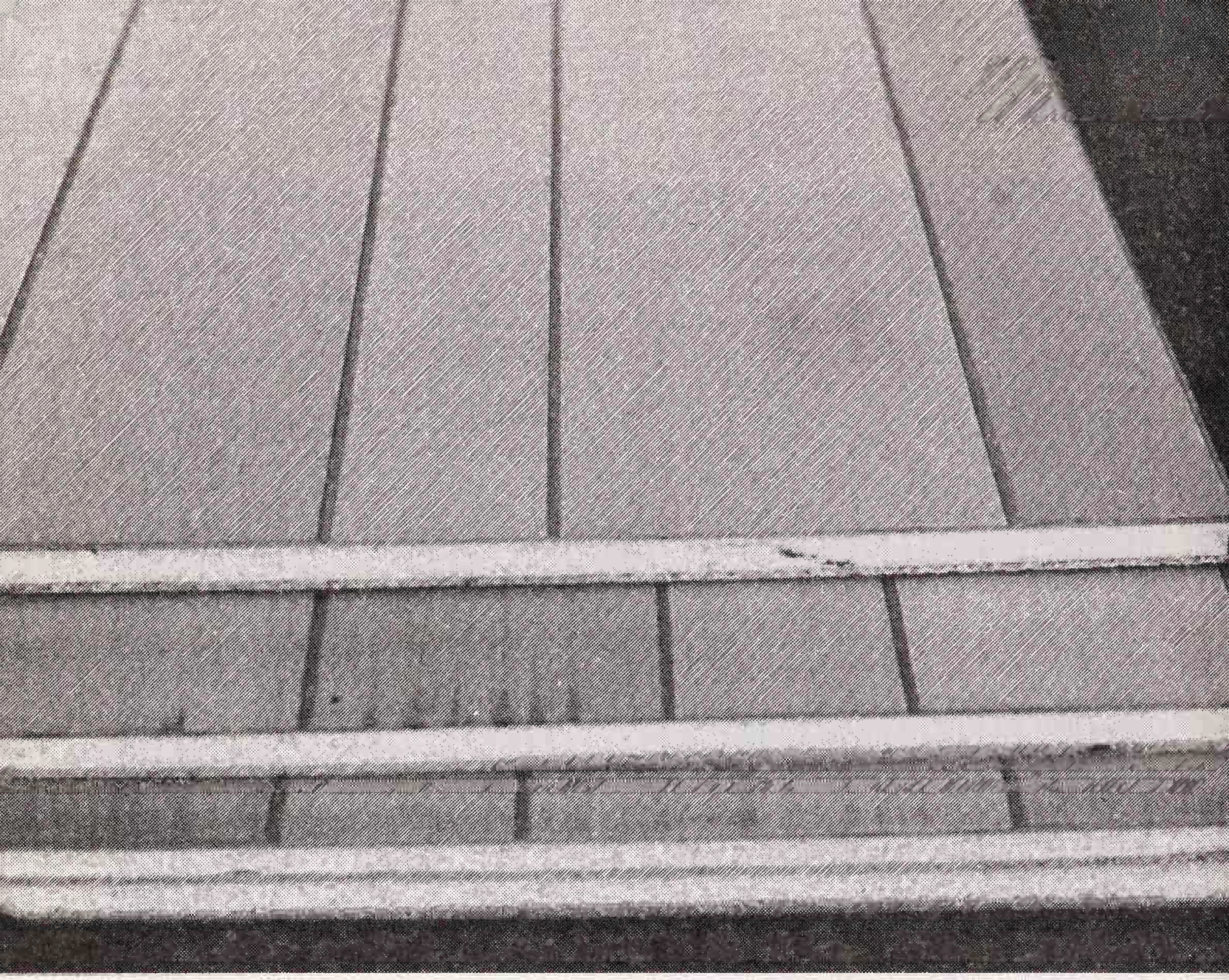

Figure 7-2 Insulated panels are made by gluing a 4′ × 8′ sheet of bead-board between a sheet of thin particle board and a sheet of inexpensive paneling.

foot sheets to the bead-board (fig. 7-1 and 7-2), and then bolted on 1×2 inch wood strips for additional rigidity and weight. Afterwards, I painted the particle board silver.

Thus when my office gets hot from too much sun, I simply place two or three of these reflecting panels on the inside (or outside) of the building.

These panels are also useful in the winter to keep the heat *inside* on those grey, sunless days or during the night. Although I have all thermopane windows, their insulation value is relatively low (under R–2). Additional covering is therefore necessary to prevent precious solar (or wood) heat from dissipating through the windows at night. So on those cold, cold nights in the winter, I'll place my four panels across the entire south side—instantly producing an insulated R–5 wall.

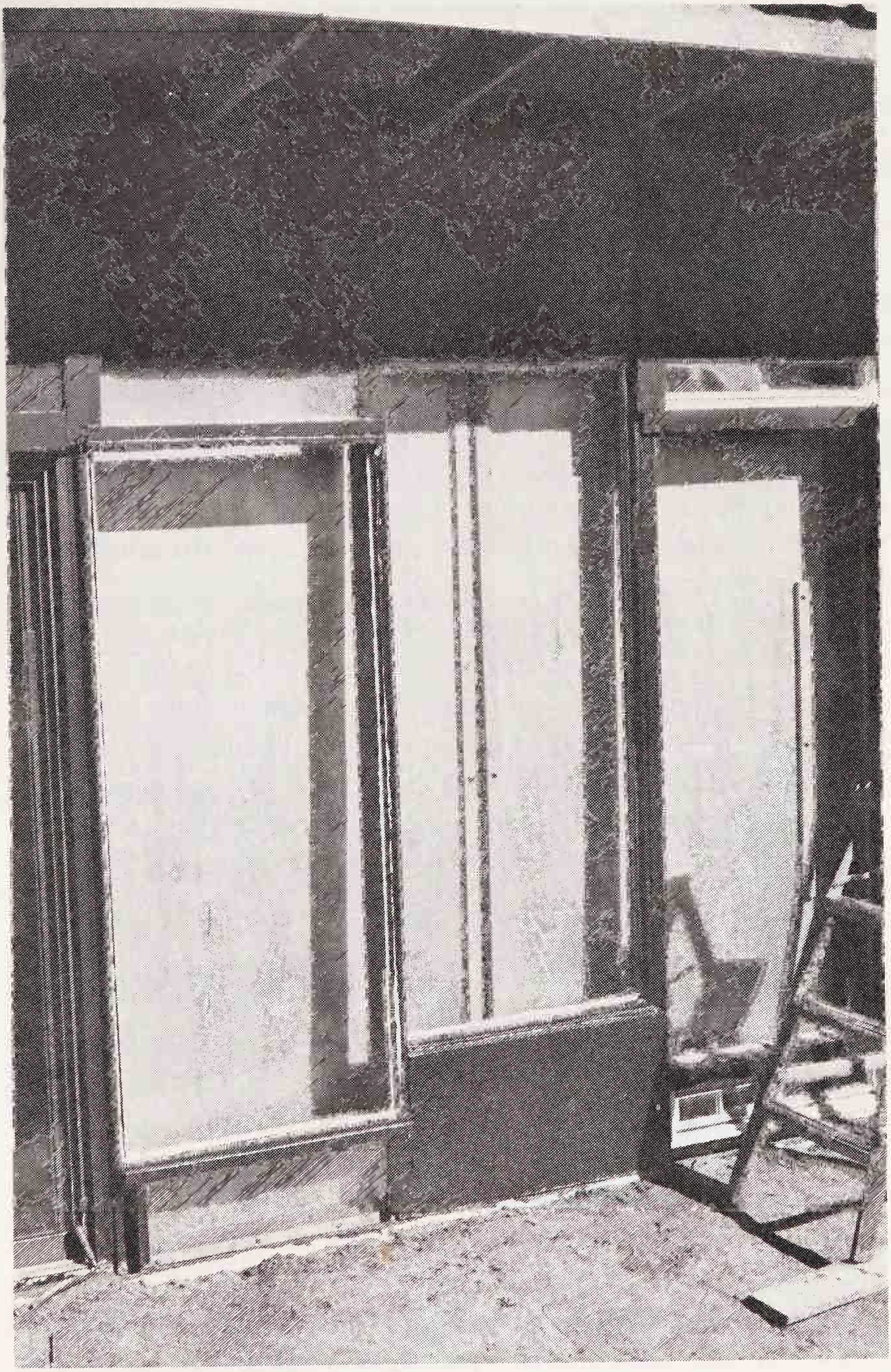

Figure 7-3 Once the panels are in place they can keep out the sun when necessary and also hold heat inside on cold, cloudy days or at night.

Waterproofing

Another important consideration is waterproofing. Indeed, I was fortunate to be building in sand—which in itself minimizes most infiltration problems. And yet, I wanted to make doubly sure. One small but effective investment you can make is to simply enlarge the roof overhangs.

I extended my roof almost two feet on the north, east, and west sides, making it difficult for even a hard driven rain to dampen the earth near the top of the walls. On the north side, I set up a gutter that takes roof runoff water and channels it (to two apple trees) a good distance from the back wall. Incidently, it must be a rather strange feeling for people to walk up to the back wall and have the eaves-trough nearly at ‘‘shoelace’’ level (fig. 7-4). Yet this is an integral part of most earth-sheltered structures that use a conventional roof.

But there is still the remote possibility that during extremely wet weather (those ‘‘hundred-year-rains’’ which seem to come about every ten years)—you could have some water pressure problems. To defend against this possibility, I painted the outside *and* the inside of my walls with two coats of a cement-based waterproofing paint. There are quite a number of these products on the market—sold mainly for basement moistureproofing. The specific brand I used was called ‘‘Bondex.’’ I mixed the paint powder with water, then wetted the wall down with a hose and finally painted it onto the wall using a wide brush. These moistureproofing products are relatively inexpensive and also look pretty good as an inside wall covering. For soils other than a good sand or gravel, I would urge using the more expensive (and more effective) bentonite or bituthene coverings.

Ventilation

Finally, there is the important question of how to design for ventilation. For such a small space as my office, this was not a particularly difficult problem.

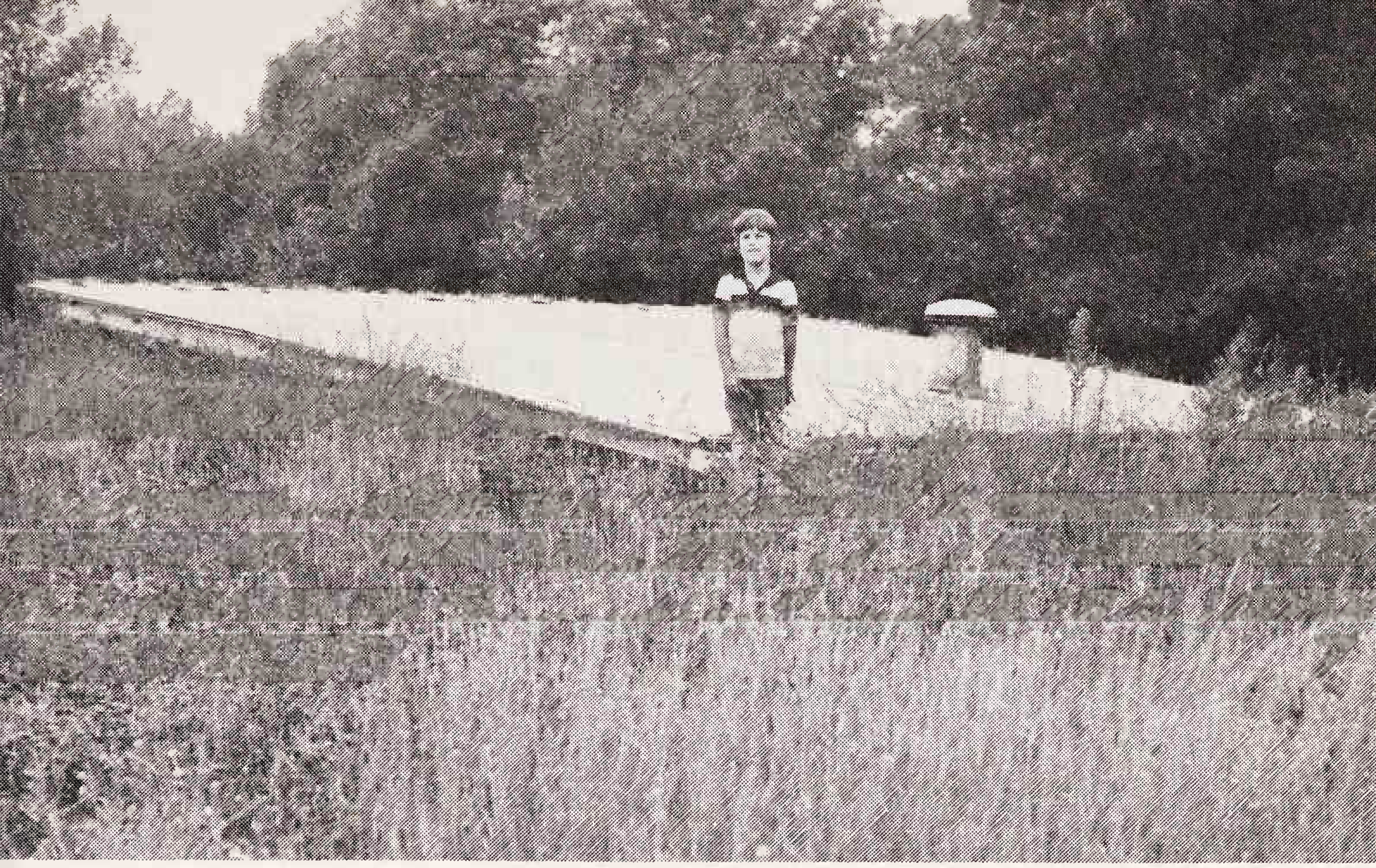

Figure 7-4 Looking at the workshop from the northeast.

The screen patio door in the southwest corner is my main source of fresh air. Also, both above and below the middle thermopane, I installed two 30 × 8 inch insulated vents; and in the east corner there are a couple of 4 inch vinyl-framed basement windows that can be opened a fraction when I might need a small amount of fresh air in the wintertime.

On the northeast and northwest upper corners (at the bottom of my supporting triangles), there are two more vents allowing for some additional cross ventilation. For a larger and longer house, it wouldn't be difficult to build up the back of your roof to provide sufficient vertical space for a few windows. They would allow for north/south cross ventilation and also let in natural light to the relatively dark side of your earth-sheltered house. In additon, these windows might be used as emergency escape routes in case of fire.

In summary, if there is any virtue to this earth-sheltered workspace, I think it is in its homely simplicity. Perhaps you are attracted to this concept and would like to build along similar lines. If so, you may be interested in reading the following chapters for more specific construction details. First topic? Getting started with the excavation, the footing, and the floor.

Chapter 8

Concrete Work

> "Concrete continues to be the most basic of all of the poor man's building materials . . . With minimum cash, but also with an understanding of the nature of concrete and with a few tools and techniques for working it, the owner-builder can expect only the best results from this marvelous material."
>
> Ken Kern

That moment right before you begin a major project is perhaps the most difficult time of all. It's when your fear is greatest, when you question your own competency the most, and when it would be not at all abnormal to have moments of black despair and even paralysis. Such was my mood for a day or so in early June of 1979.

But then you have made up your mind as to your site, your building design, and you know that your brief phone call to the man with the bulldozer or backhoe will initiate the process that will force you to begin the first step . . . which leads to the second, and so on. Thus I picked up the phone and made the call.

When the backhoe operator arrived, I asked him to dig four feet down, and to make the excavated rectangle twenty feet long and fifteen feet wide—a space large enough to allow a little more than two feet for working outside the building line. The length and width dimensions proved to be about right, but the four foot depth did, in the end, give me more dirt than I really needed, particularly when we later added the soil excavated from the front. In retrospect, I think that three or three and a half feet down from grade would have been sufficient. It depends on how large an area you want excavated out of the front.

Another thing I might do differently if I were doing it over again (a common phrase of owner/builders!) would be to point the building *slightly* easterly from its present southern exposure. Not a lot. But enough to begin heating things up a little earlier in the morning. Those who want their extra sun later in the day might consider a slight westerly orientation.

The Footing

In order to save money, I decided to pour my own footing. I used the "standard" size of 8 inches in depth and 16 inches wide. (A footing is normally as deep as the wall's thickness and twice as wide.) For those who are building deeper, or in heavy soils such as clay or silt, a larger footing (preferably designed by a building engineer) may be needed. In the heavier soils—those most vunerable to frost heaving—you would also want to have your southern (or exposed) footing go down *below* the frost line.

My first task was to lay out a rectangle the size of the building. To make this footing layout precise, I would recommend using the conventional method of squaring with batter boards and a building line (as can be seen in fig. 8-1).[20]

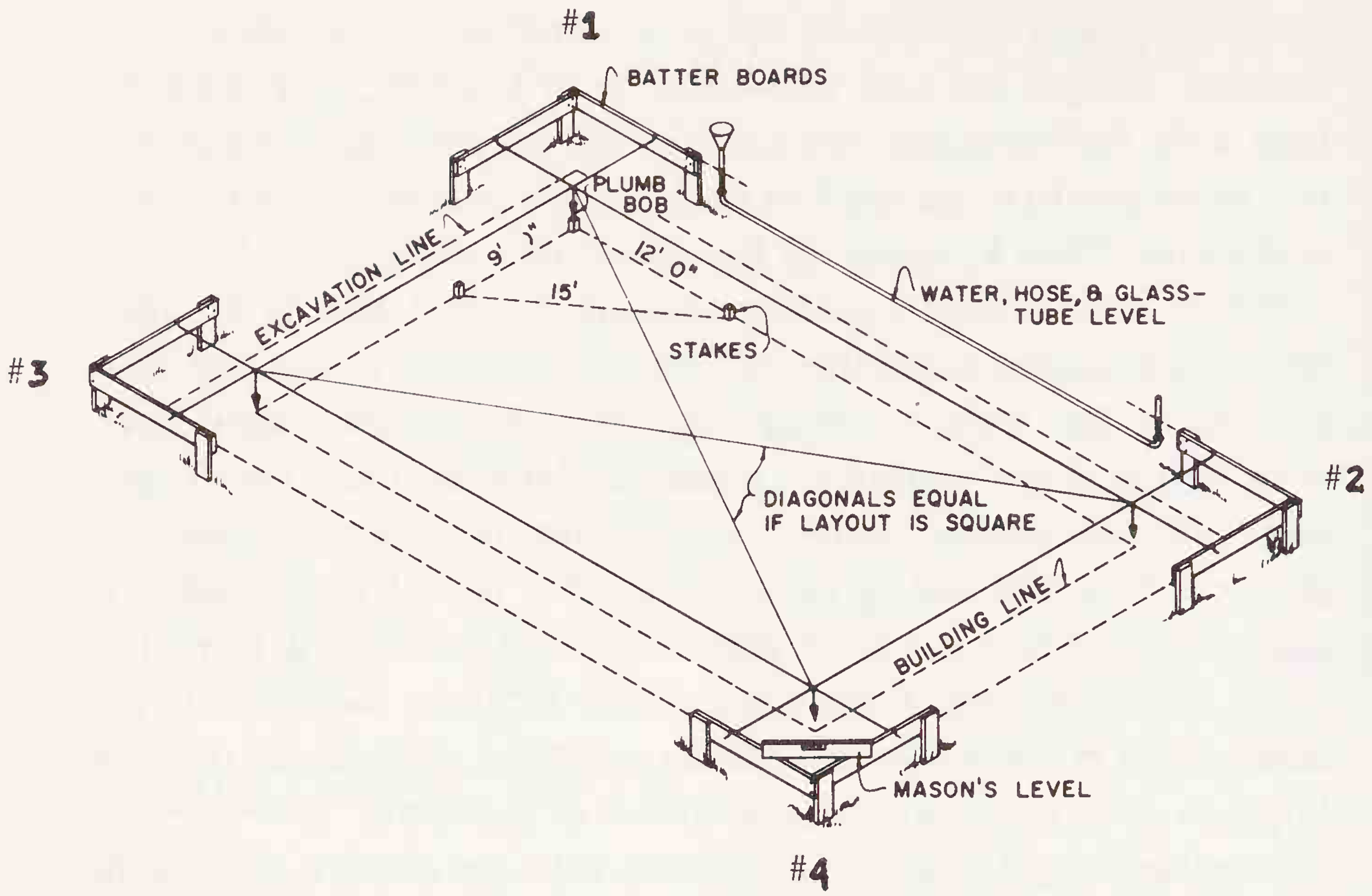

Figure 8-1 Squaring a corner using the conventional method—with batter boards and a building line.

As the diagram indicates, you must first set up your batter boards in each corner (allowing approximately a foot and a half of extra room beyond the regular building size). You then lay out your string in the approximate footing dimensions. This building line will indicate the perimeter or *outside* of the wall.

Next place a stake under the plumb bob of one corner, (say corner #1), and measure out twelve feet. Put a second stake at the 12-foot mark. Your third stake must be nine feet from the first and fifteen *diagonal* feet from the second. A little trial and error will be necessary to get that third stake properly placed. But when its set correctly, the "9-12-15" triangle will give you an exact 90 degree corner.

Now you must measure the required width and length of your building along the lines that lie directly over the stakes used for squaring. Place additional stakes in these opposite corners (#2 and #3). Next measure the distance of the long diagonal.* The fourth corner will be determined by a point that coincides with the *known* diagonal distance and the width of your building.

Finally double-check both diagonals to make sure they are *equal* in length and also recheck both the length and width of the sides. If everything comes out ok, you can be sure that your layout is very close to being a precise rectangle.

You will also want to *level* your building string in order to help level the forms later on. This can be accomplished quickly and accurately with an inexpensive line level, or as in fig. 7-1, with a hose and glass tube filled with water. Since water seeks its own level, it is a simple matter of aligning the top of the boards with the water level as observed in the glass tubes. Again, refer to fig. 7-1 to see how this is done.

Next comes the hard work of digging a trench large enough to hold the forms for the footing. My trench was sixteen inches wide plus the width of the two forms. The face of the inside form was placed twelve inches from the building line while the outside form would be four inches from the line. (See fig. 8-2.)

I must confess that in this early stage of work, especially in digging and installing forms, I found myself operating at what seemed at times like peak *inefficiency*. It was akin, perhaps, to that awkward, bumbling stage of first getting to know someone.

I remember making a number of small blunders and of having infuriating lapses of memory. At one point I stepped on my glasses (forgetting, of course, where I had put them). There was also some difficulty in getting used to stiff muscles, little cuts and scrapes, dirt in the eyes, and other irritating assaults on the body. Again, I think it will be easier for you if you *expect* both inner and outer disequilibrium as you first begin working.

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*You may want to double check your measured diagonal with the mathematical formula; $(\text{diagonal})^2 = (\text{length})^2 + (\text{width})^2$. For example, if your width is 10 feet and the length is 15 feet, you would have $10^2 + 15^2 = \text{diagonal}^2$ or $100 + 225 = d^2$. Thus you should get 325 when you square the distance of your measured diagonal.

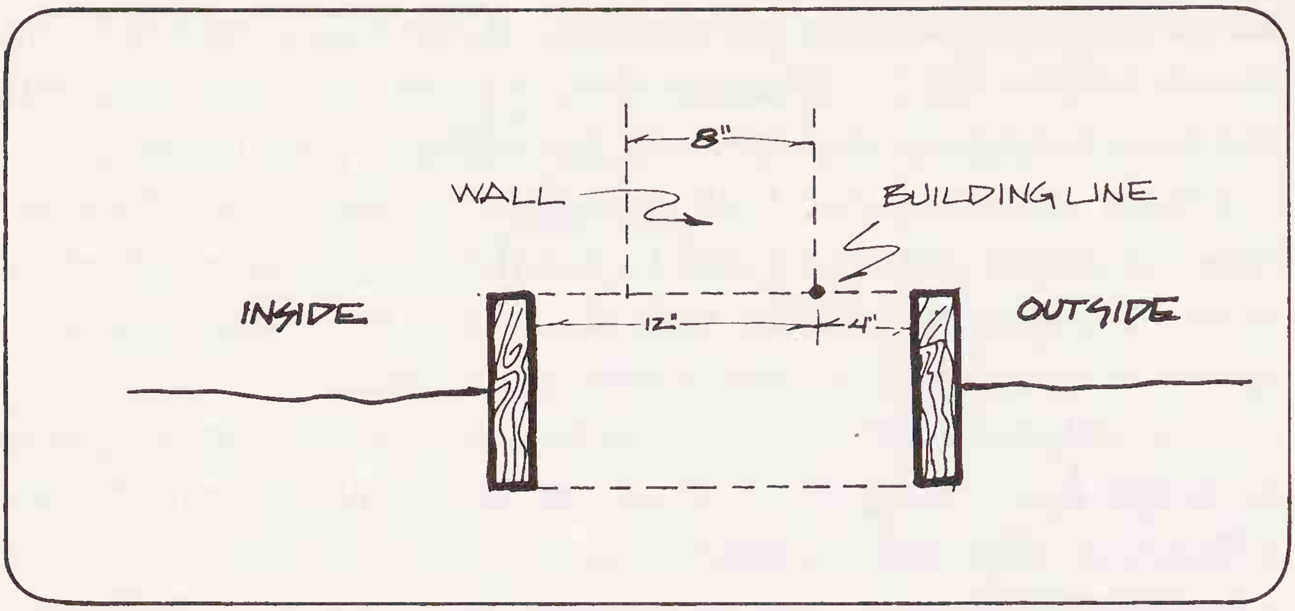


Figure 8-2 All measurements in regard to footing dimensions begin from the building line.

Continuing on the trench, I was now ready to compact the soil. This can easily be done by sprinkling water and stomping down on the dirt within the footing.

Next came the footing insulation—see fig. 8-3 (and later the horizontal steel reinforcing rods). I also tied the opposite forms together with lengths of 1×2's. This last step is important as you will soon discover that poured concrete can exert considerable lateral pressure. I've known a number of beginning builders (including myself) who have had the sad experience of watching their forms spread apart under the force of flowing concrete.

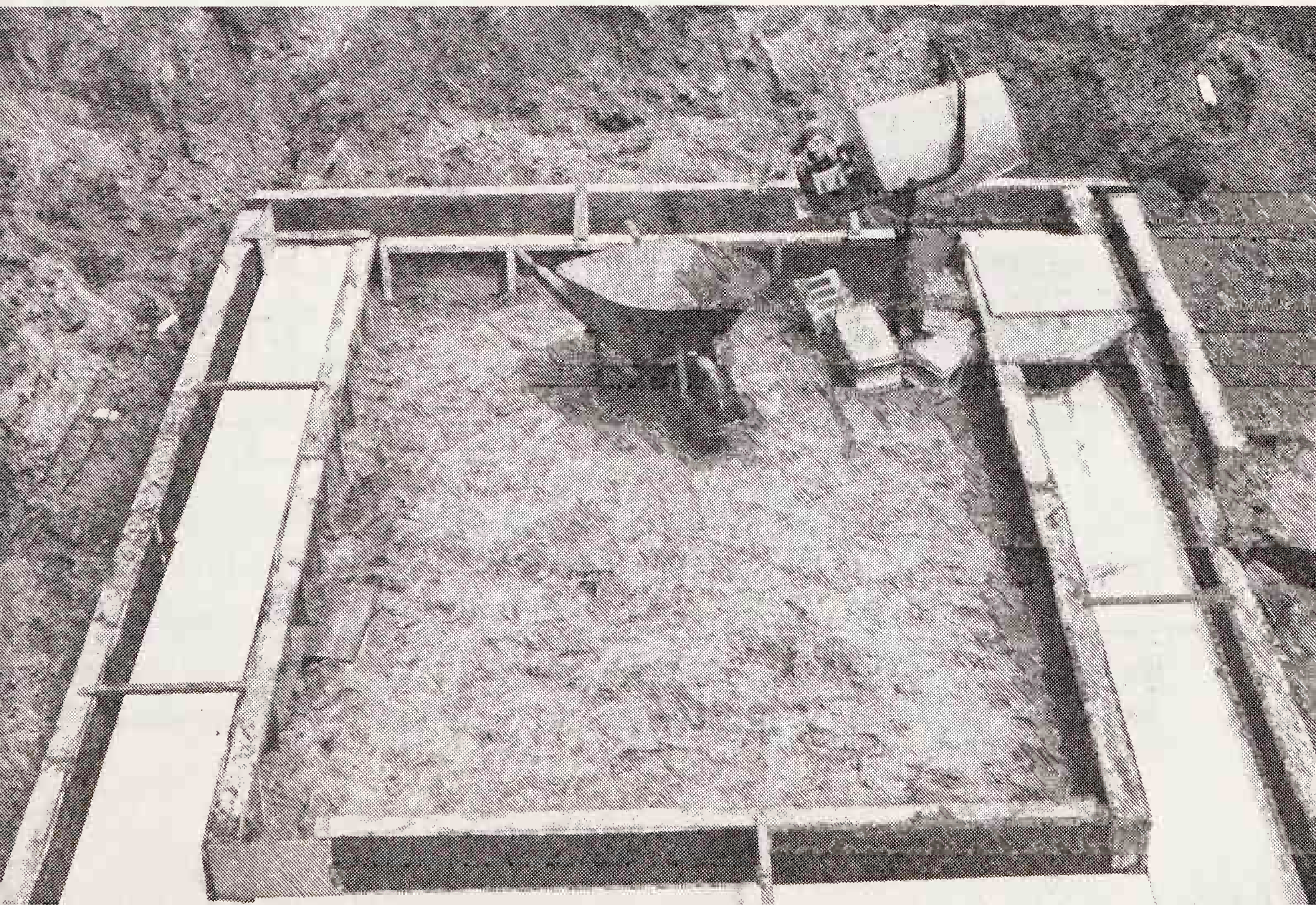
A friend and I were now ready for the first pour from our small mixer. As we mixed and poured, mixed and poured, we were a little surprised to discover how much human energy and time it took to complete this relatively small footing—especially if you are going to do it all at once. For a larger footing, you'd probably want to go the ready-mix route.

After leveling the concrete with a 2×4, we then put some *vertical* reinforcing rods into the footing. These steel rods help tie your footing to the soon-to-be-poured wall. Remember too that it's always a good idea to "cure" the concrete, to keep its surface *moist* for a few days after the pour. This will have the effect of prolonging the "hydration" or hardening process, thus making the concrete significantly stronger than if you had let it dry out immediately.

As I mentioned earlier, the forming and pouring of the walls was done by professional concrete workers. And after working so hard on the small footing, I was indeed impressed with the great ease and speed of the ready-mix approach. True, it is expensive. Also, the brief invasions by huge, noisy trucks may put you off. Yet contracted forming and ready-mix may well be worth it in saving you both time and energy.

I have also learned that it pays to shop around for a concrete contractor. For example, a firm located outside of your particular area may give you a quote surprisingly lower than a local outfit who may be charging monopoly prices. When discussing your walls with the contractor, be sure to request *pilasters* in front, and also tell him that you want anchor bolts all the way around the top of your wall as well as up and down the pilasters (fig. 8-4).

Figure 8-3 Footing forms and insulation before placement of the horizontal reinforcing rods.



The Floor

Generally speaking, the floor comes *last*, that is, after the roof has been completed. This is to allow time for your walls and footing to settle.

For my small office space, I decided to go ahead and do the floor on my own. I wanted to save money of course, but even more important, I simply didn't want another large truck tearing up our yard and hay field. Besides, I saw no reason why a floor slab couldn't be worked on in small sections—in a quiet, non-rushed, personal kind of way.

I first had to build up my south footing with an additonal course of 8 inch blocks using the "surface-bonding" method described in chapter three. I then filled the interior with gravel and sand up to the top of the footing. At this point remember to leave a little sand on the top of the footing so it and the floor slab will not be bonded together.

After watering the gravel fill, I put down a one inch layer of rigid polystyrene. My floor sections then would be exactly the

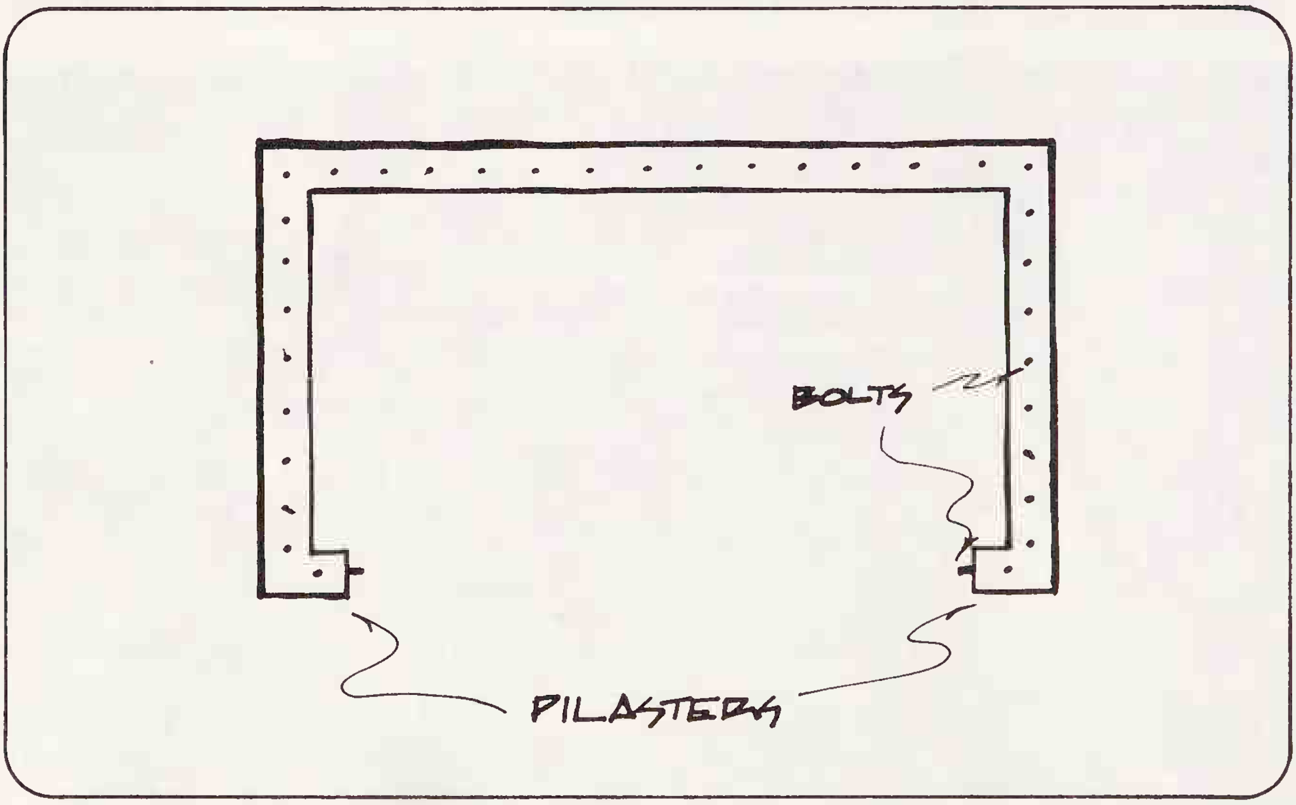


Figure 8-4 A top view of the wall with pilasters in the front and anchor bolts inserted on top of wall.

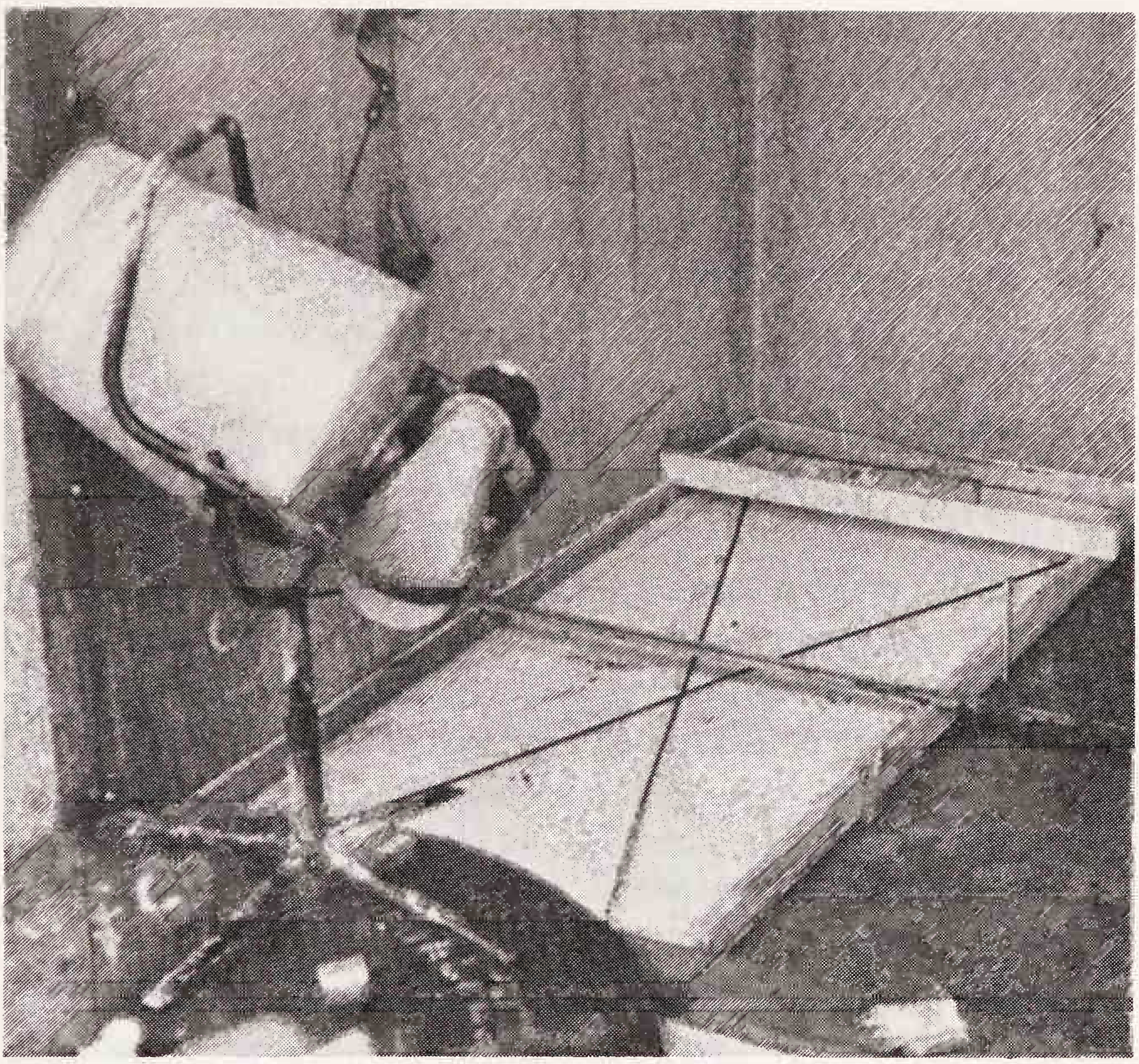


Figure 8-5 The forms for the first section of flooring are in place—ready for concrete to be poured.

same width as the insulation (four feet). Treated 1×4's were placed around the perimeter as section forms. As can be seen in fig. 8-5, another 1×4 was added to complete the forming rectangle. This board must be securely staked during the forming but will, of course, be removed after the section pour has set up a bit.

I then double-checked my forming boards to make sure they were level both lengthwise and across. Finally, I was ready to begin making concrete.

Somehow this slower paced approach was far more enjoyable than our high-pressured job on the footings. That work forced us to keep going and going until it was all finished. For the floor, I would take my time.

I enjoyed, for example, listening to the varied moods of the mixer—sometimes lightly sloshing water, other times groaning heavily with thick concrete. There was also the crunch and grating sound of wet gravel. Dump the mixture out, and it goes ''plop . . . plop . . . plop.'' I would then jump into the form (with rubber boots on, of course) shovel in hand, and try to push this gray, gravelly mush (a substance that seems to love gravity) to the back.

I was now ready to ''strike it off'' by pulling a 2×4 over the forms. This can be a tough job that may exhaust you before you know it. I remember making what I thought was my last sweep over the top—only to discover some ''mysterious streaks'' down the middle of the concrete bed. These indentations were caused by clumsy fingers that had gripped the striking board too low. I did, of course, have a chance to make a final smoothing with a wood float and then with a steel trowel after the concrete had set up a bit.

My plan was to finish one section per day. But like most repetitious jobs, once you've done it the first time, it becomes much easier thereafter. The four sections were completed in two and half days.

Thus with the finishing of the footing, walls and floor, the concrete work for my little building was complete and I could now turn to some of the other major tasks that lay ahead.

Chapter 9

The Roof

> "To spend has become reasonable, accepted, compulsive. Not to spend seems to be the proposition which now requires the longer argument. Nevertheless, the way to save money in a house is to search out the things we have been told we need, but don't . . . The roof is the most distinguishing feature in a house. It is also the most expensive part . . . it behooves us to think carefully about how to get the most roof for your money."
>
> Rex Roberts

Roof Design

The shed roof must be the simplest type of roofing system for the inexperienced carpenter to build and maintain.

It's a roof that is not only easy to construct and relatively safe to work on, but it's one that also makes for a pleasing ceiling on the inside. When my wife and I built our "pole-house" in the summer of 1972, we decided to use a shed roof with a pitch of *2* (rising two inches for every horizontal foot). Our shed roof allows us to have an open ceiling and thus provides more "visual space" than a conventional flat ceiling—an important plus for small houses. We describe our building experience in a small book, *The No-Mortgage Home.*[21] And since we have been quite satisfied with this roof design for our house, I felt confident in using it for my office/workshop.

Next, what about roofing material? I suppose most people automatically think of using asphalt shingles since they're the most popular roofing material. We too were tempted to use shingles on our pole-house, but thought twice about it after reading what engineer Rex Roberts had to say about the subject.

> Shingles are ghosts from the past. The cabin builder, working with the material at hand, split pieces of wood and put them side by side on his roof. He staggered each succeeding row to cover the cracks in the row below. It was an improvement over pine boughs or grass.

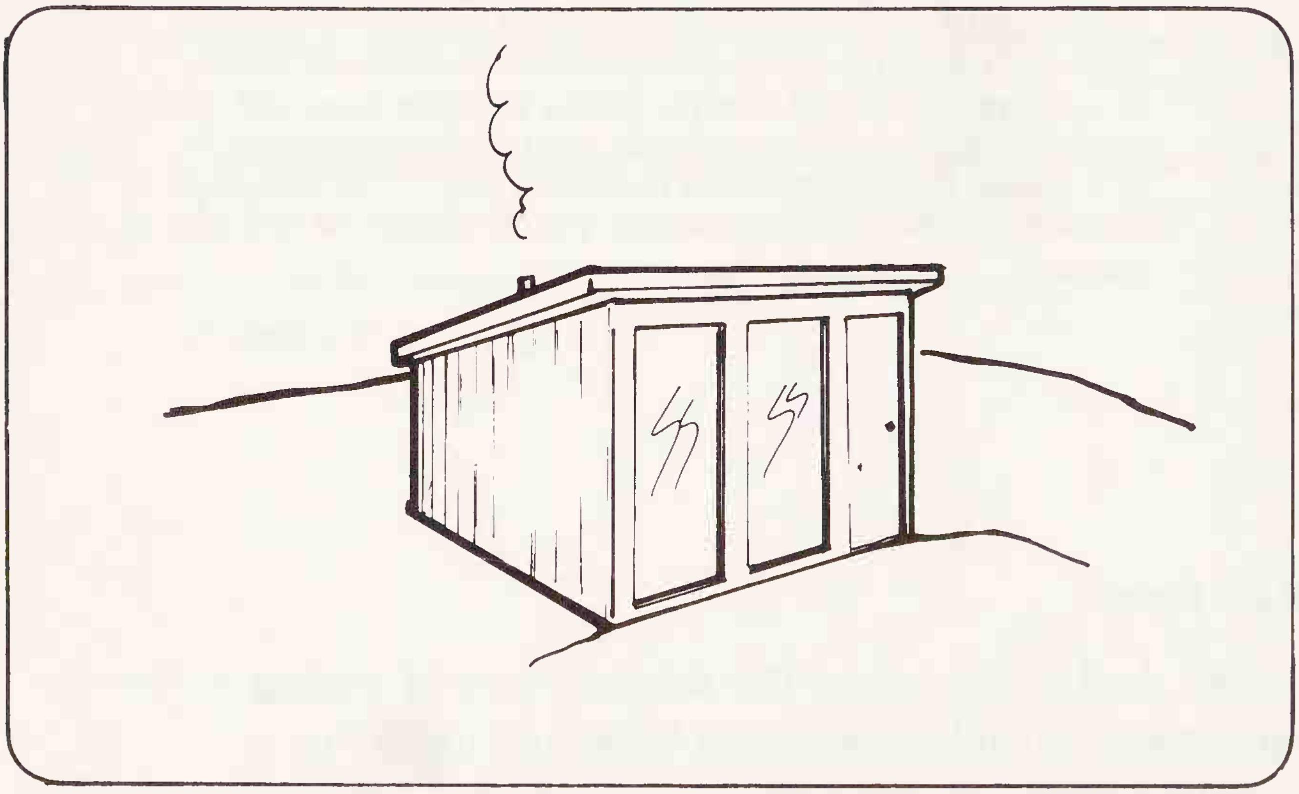


Figure 9-1 The shed-roof is the simplest kind of roof for the novice to build.

> The small size of his wooden shingle had created a pattern of horizontal lines crossed by staggered vertical lines. Many people came to believe that if this pattern were not exhibited, it wasn't a roof. To satisfy this belief, manufacturers take perfectly good roofing material, cut it up into little pieces, then cut slots in the little pieces so that the end result will look like little pieces of wood . . . The imitation shingle, with holes cut in it, has used twice as much weight, taken twice as long to lay, cost twice as much, and will require earlier maintenance. This is a heavy price to pay for imitation.[22]

We decided to follow Rex's suggestion and use double coverage roll-roofing. I might add that we've been completely satisfied with this roofing material on our modestly sloped home roof. (Incidently, when used along with roofing cement, double coverage roofing *can be* effective for slopes as low as one inch to the foot!)

Yet despite our success with roll-roofing, for my office I decided to go one more step in the direction of durability and low cost. I would try ordinary galvanized steel as suggested by the Nearings in *Living the Good Life*. Considering all the advantages, I am indeed surprised that this type of roofing is not used more frequently by owner/builders.

For one thing steel is less expensive than petroleum-based asphalt roofing materials. It's also more durable and, for shed roofs, considerably easier to install than shingles or roll-roofing. In addition, the galvanized steel is fireproof, and its shiny surface reflects the sun in the summer and allows for easy snow removal in the winter. If you don't like the shiny appearance, you can paint it or purchase it new in a variety of unobtrusive colors. In short, galvanized steel (or aluminum) is a roofing material that's hard to beat.

Roof Framing

Having made a final decision on my roof design and covering, I was now ready to begin building the roof itself. My first task was to build up the roof support "triangles" on both the east and west walls. I began with a 2×4 sill plate secured by anchor bolts that had been installed in the wall by the concrete contractor. I also had to install a barrier to prevent direct contact between the wood and the wall—otherwise the moisture absorbing concrete would, in time, rot the sill. Fiberglass ‘‘sill-sealer’’ or insulation board are effective for this purpose.

To locate the points on the sill plate that correspond to the anchor bolts, I simply held my 2×4 over the bolts, and then tapped the wood with a hammer. This left slight indentations in the wood indicating where to drill the holes.

With sill plates firmly bolted in place on three sides (plus a

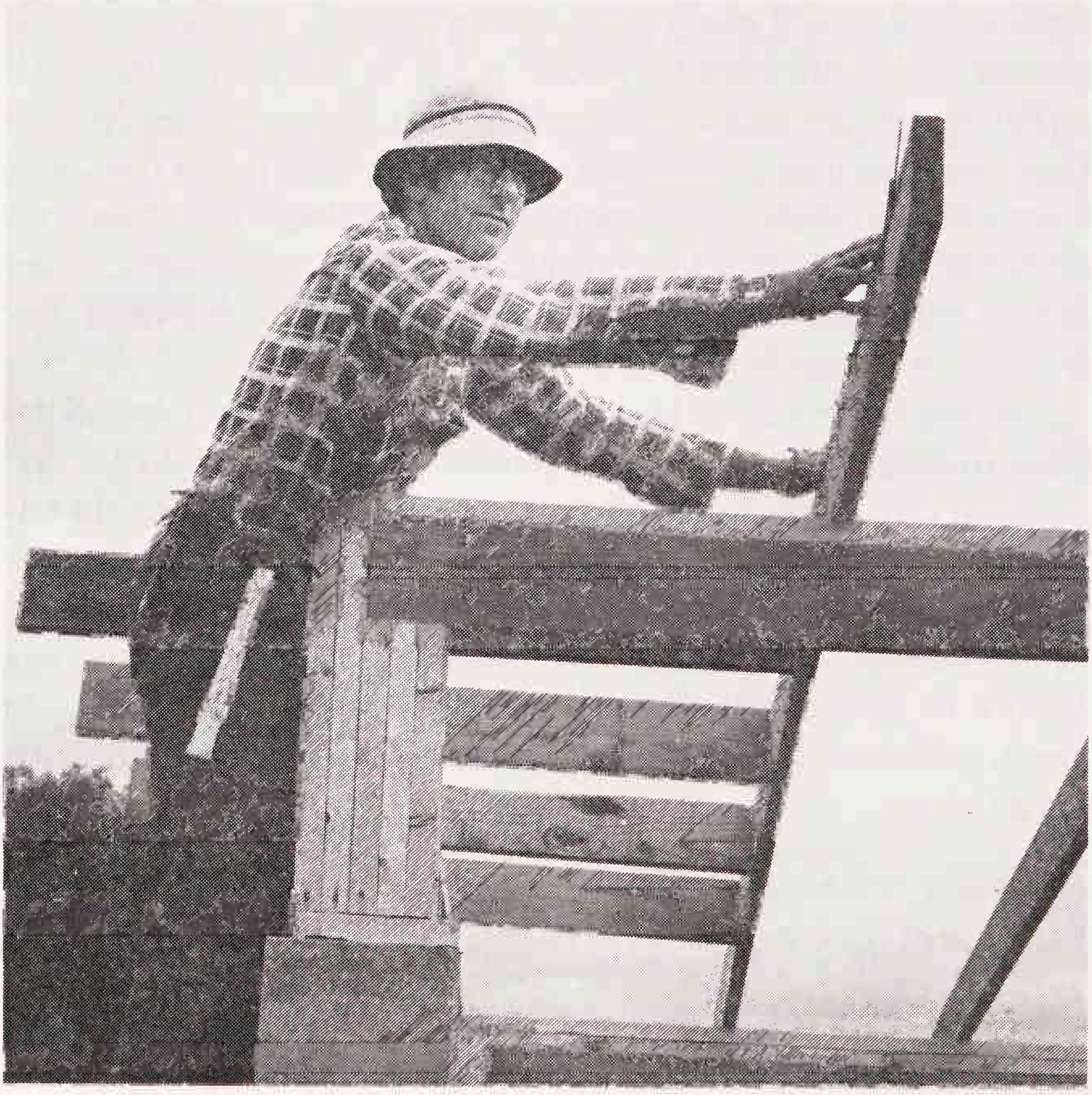


Figure 9-2 Note that the outer two studs are turned sideways for easier nailing into the roof beam.

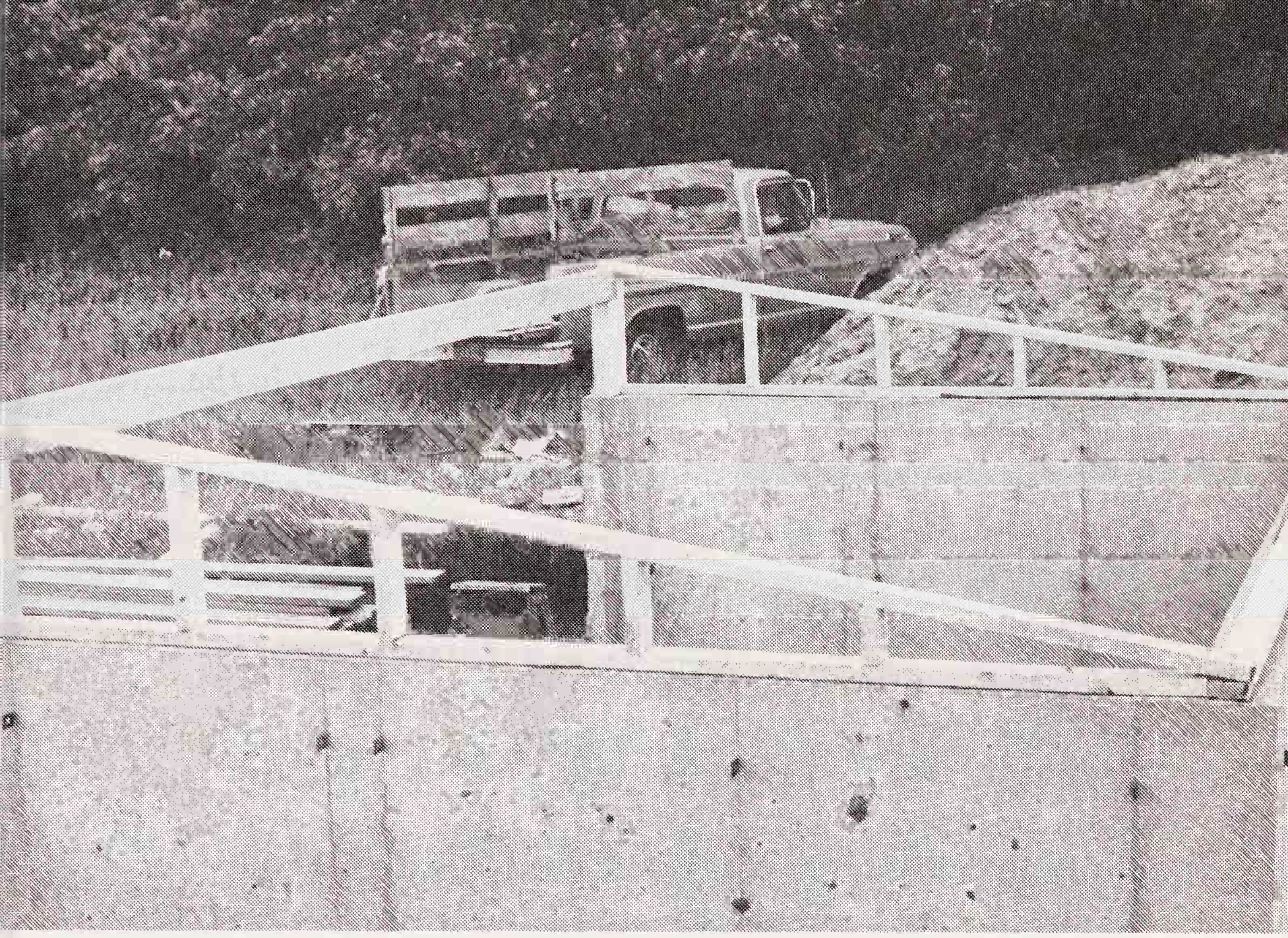


Figure 9-3 View from the northwest: walls and supporting triangles

small plate over the pilaster), it would now be relatively easy to build up the triangles—beginning with the top-plate, i.e., the "hypotenuse" of the framing triangle. This plate will, in turn, be the support for the "lookout" rafters and therefore has to rise at the rate of two inches per foot. Since the horizontal part of the triangle is ten feet in length, the front must therefore be twenty inches higher than the back.

Next came the short studs which support the top-plate. These small vertical 2×4's are spaced two feet apart and are nailed into the sill and top-plates. As you can see in fig. 9-2, the front two studs (on the outside) are turned sideways so that they can be nailed more easily into the roof-beam, (the large beam that spans the front of the building), while the others are all on edge (fig. 9-3).

The front roof beam was constructed from two 2×6's nailed together. The ends of this beam rest on three 2×4's rising vertically from the pilaster sill-plate. Again, you may want to refer to fig. 9-2 to see how this was done.

At this stage of construction, I had a couple more things to do before I could install the main roof rafters. First, I needed a temporary support under the front roof beam. This 4×4 post would eventually be removed when I was ready to "fill-in" the south wall.

Secondly, instead of putting "birds-mouth" cuts in the rafters, I decided to make a small plate that would be positioned on top of the double-beam. This piece serves as a "resting spot" for the north/south rafters (fig. 9-2). Since the roof slope is a *2 to 12* pitch, I would have to bevel the three-inch-plate approximately ½ inch as shown in figure 9-4.

You can make this bevel quite easily on a table saw, or with a little patience, with a hand crosscut saw. It doesn't have to be perfect. In fastening this plate to the main beam, I'd recommend using both nails *and* glue. By laminating with glue, you'll increase the beam's load carrying capacity by almost 50%!

Now for the main-rafters that run north and south. These are 2×6's, each sixteen feet long—enough length for the ten foot span plus the approximate three-foot-overhang in the front, two feet in the back, and a foot or so for the two wall thicknesses. With tape measure in hand, I marked two foot intervals on both

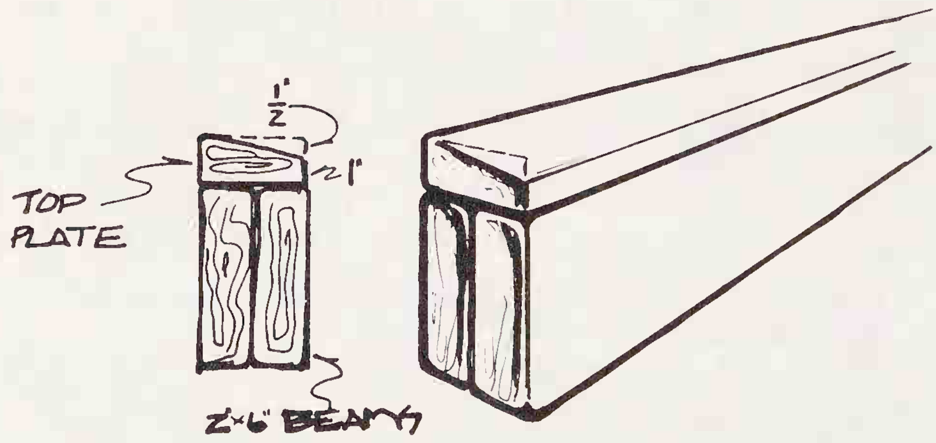


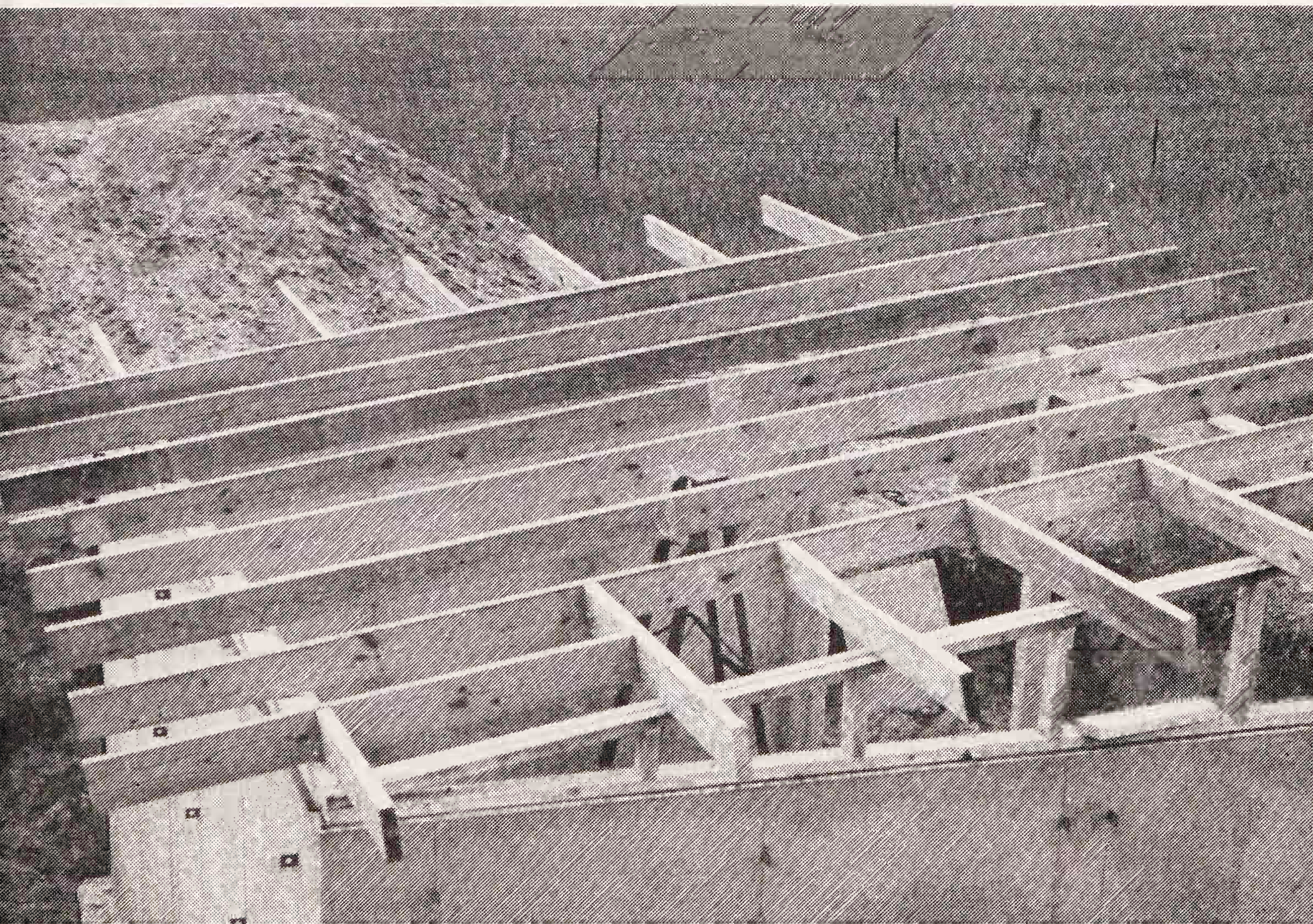
Figure 9-4 A detailed view of the front beam. Note the small plate on top of the double-beam.

the back sill and the front beam. Rafters were then lifted up, positioned, and toenailed in. Although one person can do this work, it's much easier and faster with two.

And as you install your rafter system, you'll be amazed to see how *rapidly* the overall skeleton takes shape—especially in contrast to those early days when you could labor over some invisible detail (like setting up the footing forms) for what seemed like an interminable period of time. The psychological uplift from framing your roof is something to look forward to.

Assuming that the regular north/south rafters are securely in place, it's now time to install what are called the "lookout" rafters. These 2 × 6's extend out on the side to support the east/west overhangs. My lookout rafters were butted and nailed against a north/south rafter that was four feet in—and then toenailed to the top-plate on the side. Generally speaking, you should design lookout rafters to be two-thirds on the inside of the building and one-third on the outside (the overhang). Figure 9-5 shows the roof framing detail with all the rafters in place.

Figure 9-5 Now all the rafters are in place. Note the lookout rafters extending out of the east and west walls.



To protect the rafter ends from moisture, a 1×6 fascia board should be nailed into the ends of the rafters all the way around the roof. In addition, the fascia board gives the overall framework added stability. Also improving roofing support and rigidity are the two foot long 2×4's that serve as *blocking*. These boards rest on the back sill as well as on the top-plates on the east, west, and south sides. They are wedged and nailed between each rafter and hence prevent the rafters from tipping (fig. 9-6).

Moving up from the roof framing work, my next job was to install roof decking. I used ½ inch plywood simply because I was able to buy it secondhand. Normally, however, I would have chosen one inch rough-cut boards to get a more solid nailing surface for the metal roofing. If you use plywood, the sheets should be nailed with 2 inch nails spaced six inches apart on the edges and a foot apart elsewhere. At this point in the roofing process, some builders recommend a layer of felt paper underlayment to cushion the metal during hail, wind, etc., and thus prevent the roofing nails from loosening up over the years.

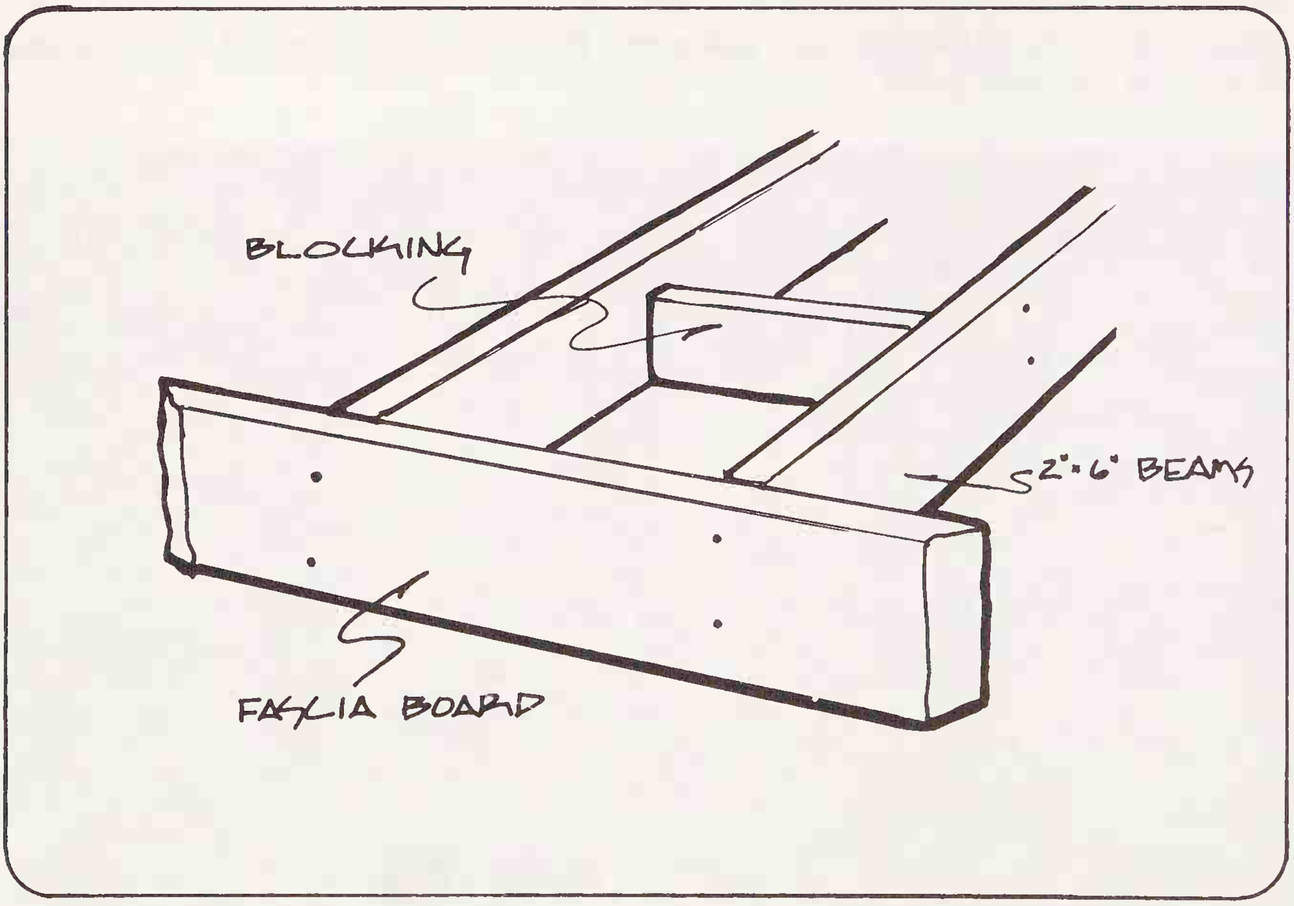


Figure 9-6 Both blocking and fascia board can be used to add rigidity to the roof structure.

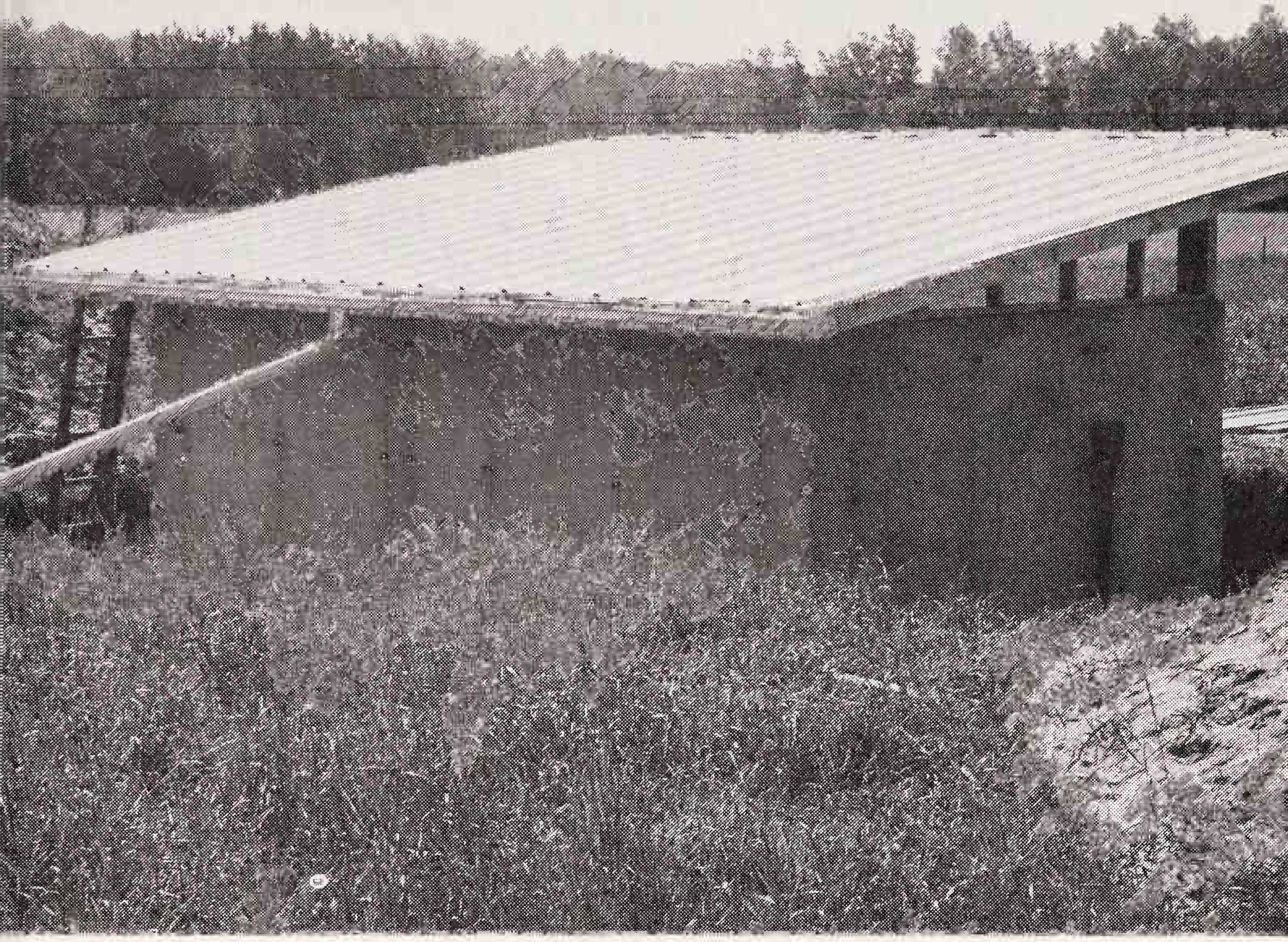


Figure 9-7 View from the northwest side of the completed wall and roof.

Finally, I was ready for the galvanized metal. I ordered special sixteen foot sheets from our local building supply house. This length would allow me to cover the roof without any north/south lapping. Special orders like this take an extra week or two, but they're well worth it in terms of getting a more water resistant roof—an important fact when you consider the roof's relatively low pitch.

I did, however, make the mistake of ordering *exactly* sixteen foot lengths. I should have allowed an extra three or four inches for drip edges. Since I didn't, I later had to buy additional steel costing me, of course, extra time and money.

For my small project I used seven steel sheets where each sheet covered a width of three feet. These sheets, in turn, had lapping ridges that were three inches wide. Using galvanized nails with lead washers, I nailed directly into the ridge at two foot intervals.

My final roofing task was to install a downspout system to prevent collected rain water from draining next to the back wall. The completed roof can be seen in fig. 9-7.

The Ceiling

Some of my neighbors who stopped by every so often were now beginning to understand the ''earth-berming'' principle; yet they still had difficulty going along with my open ceiling.

More specifically, they were wondering where I was going to get my roof ventilation. Most houses, especially in northern climates, need continuous air movement *above* the ceiling insulation to remove excessive moisture in the wintertime and also surplus heat which, if not allowed to escape, could cause the common problem of ''ice-damming.'' Indeed, my neighbors had a point; if I were to insulate with six inches of fiberglass, how could I ventilate the roof?

I am indebted to my friend Stan Smith for suggesting a solution to this problem. Stan's idea would not only provide me with a low-cost system for ventilation but would also have the effect of strengthening my roof rafters. What I did was cut a ten foot 2×4 down the middle. Then I glued and nailed one of these 2×2 strips onto the bottom of each rafter (fig. 9-8).

I could now staple six inch insulation between the rafters and still have a one and three-quarter inch air space above the insulation. To prevent insects and nesting animals from bedding in the insulation, I stapled small screens above the blocking. The workshop/office roof now has efficient north/south roof ventilation.

As I mentioned earlier, there is an additional structural bonus to this rafter modification. By gluing a 2×2 on a 2×6, I get very nearly the strength of a 2×8 (which according to load-bearing formulas should be about *twice* as strong as the original rafter*.) I verified this conclusion with an official framing-span table for roof rafters which showed that a 2×6 on a twelve-foot-four-inch span can safely hold twenty pound per square foot, whereas on the same distance, a 2×8 will support a load of forty pounds per square foot.

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*The load-bearing capacity of wood increases with the *square* of the depth of the member. Thus, eight squared is almost twice as much as six squared!

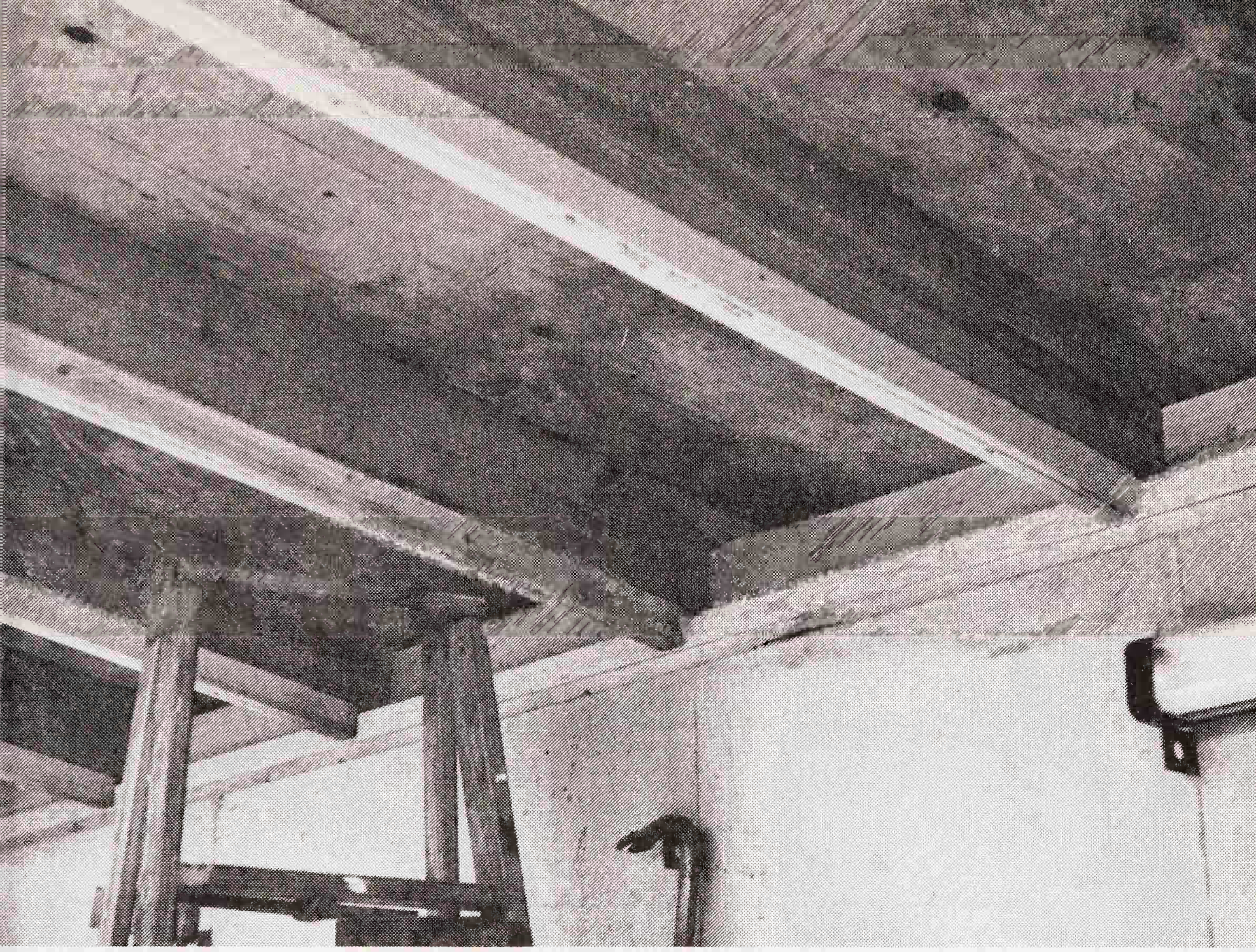


Figure 9-8 **To make extra room for ventilation and add strength to roof rafters, 2″ × 2″ strips are nailed and glued to the bottom of each rafter.**

Once my insulation work was complete, I could begin working on the ceiling itself. I first stapled a continuous plastic vapor barrier on the bottom of my ''new'' 2×8 rafters and then nailed on an interior ceiling covering.

I decided to use drywall (often called sheetrock), since this material provides an excellent fire barrier. Those of you who have worked with drywall know how heavy it is. You should, if possible, get someone to help you put it up. Also, we discovered that it was much easier when we used a ''T'' board support which allows you to prop up part of the drywall from the floor.

When installing these panels, be sure to use the special ringed 1¼ inch nails that are designed for this purpose. Nails should be seven inches apart up and down each rafter. Of course, you can finish off a dry wall ceiling a number of ways to suit individual taste. For my workshop/office, I simply painted it white (two coats) with a paint roller. It looks surprisingly good even without the conventional taping and drywall compound.

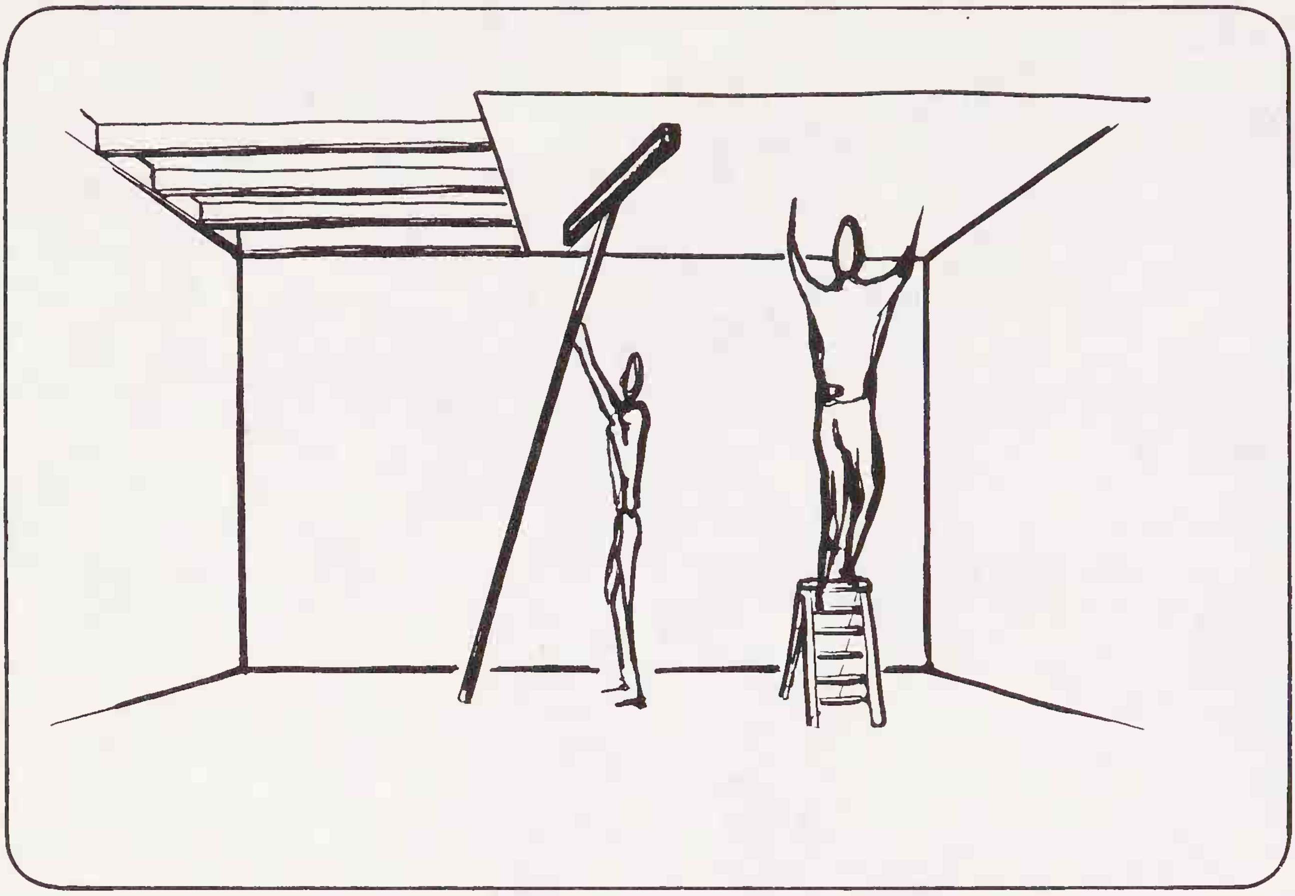


Figure 9-9 If using drywall for the ceiling, it's much easier to install it with the help of a T board support.

It was now around the summer solstice and my roof was nearly complete. With a hot June sun overhead, I remember sitting inside the complete shell with its new ''silver bonnet'' on top. It felt nice and cool. Of course, there was lots more to do. I had not yet begun working on the front, and there were also the retaining walls and backfilling ahead of me.

But I got caught up in the lazy mood of this warm summer day. Gentle breezes wafted inside. A few curious bees and butterflies made their quick surveys into this strange new space that had suddenly appeared in their clover field. They flew in and around, then went on their way.

Chapter 10

Finishing Up

> "There is some of the same fitness in a man's building his own house that there is in a bird's building its own nest. Who knows but if men constructed their dwellings with their own hands, and provided food for themselves and families simply and honestly enough, the poetic faculty would be universally developed, as birds universally sing when they are so engaged?"
>
> Henry Thoreau

Retaining Walls

The nature and construction of retaining walls are subjects which conventional builders give little consideration. Yet for those who are building earth-sheltered homes, the retaining wall becomes an important topic of discussion; for anytime you combine wall berming with the need for entry and window space, you'll need two or more of these special purpose walls.

A majority of today's underground houses use reinforced concrete for their retaining walls. In addition, their walls are usually "free-standing," that is, they are not directly attached to the regular walls. This "thermal break" requirement prevents stored heat from "bleeding" into the massive concrete and dissipating into the air. It also makes them more expensive—as footings have to be larger and retaining walls thicker than regular structural walls around the home. Thus many underground builders wind up spending thousands of dollars for these massive concrete wings that just jut out from the corners of their subterranean homes. For the low-cost builder, I think treated wood or stone can be an attractive and inexpensive substitute for concrete.

Perhaps the least expensive way you can go is to simply build up a modest three or four foot stone wall and grade the soil diagonally up the back as in figure 10-1.

This method, however, exposes a triangular section of your wall to the open air and you will therefore lose some of your earth berming efficiency.

Terracing is another low-cost possibility. In fact, one of the most attractive retaining walls I've seen was a series of terraces

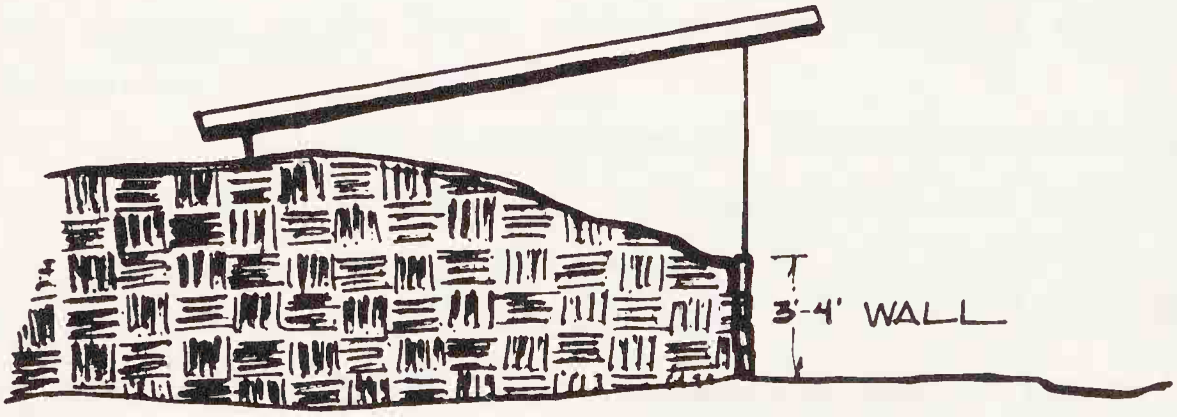


Figure 10-1 The easiest and least expensive way to berm the exterior of your earth shelter is to build a short retaining wall.

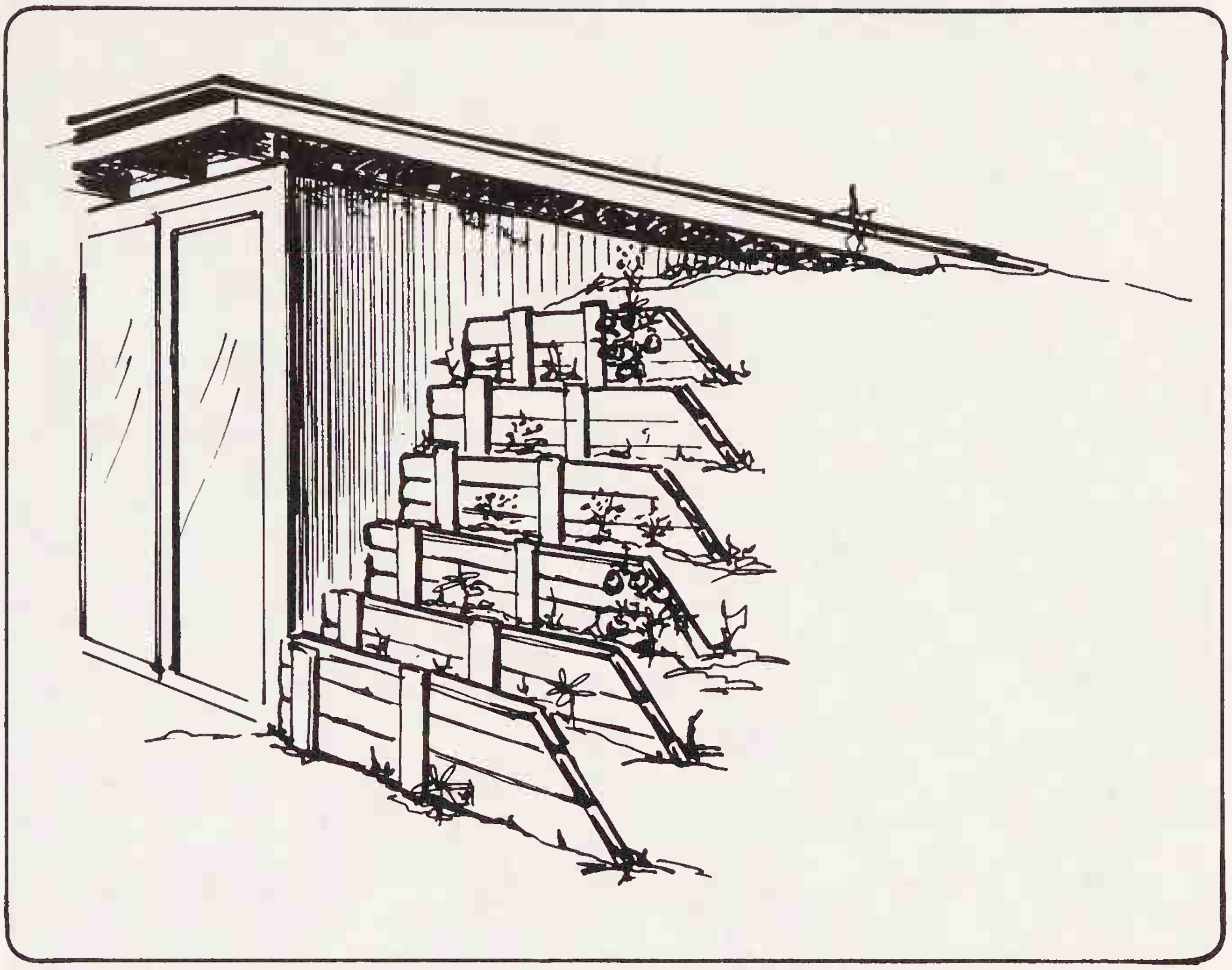


Figure 10-2 Terracing with treated wood or stone can be an attractive solution for retaining soil.

braced by treated wood. Each flat terraced area in turn provided a space for flowers and vegetables.

It is also possible to terrace with stone. For a full-height wall, large flat boulders (such as those used by Robert Roy) can also be both attractive and inexpensive—if you have the machinery available to lift and position the stone.

For my little building, I decided to make retaining walls out of treated posts and boards. I used 4×4 inch posts fourteen feet long. Obviously one cannot just ''stick'' these uprights into the ground with a post-hole digger and expect them to hold up against the tremendous pressures exerted by the backfilling of eight feet of dirt. To give the posts the necessary stability, I put them in concrete footings. Each footing was four feet long, one foot wide, and four feet deep.

For a job like this, I found that I could mix cement and aggre-

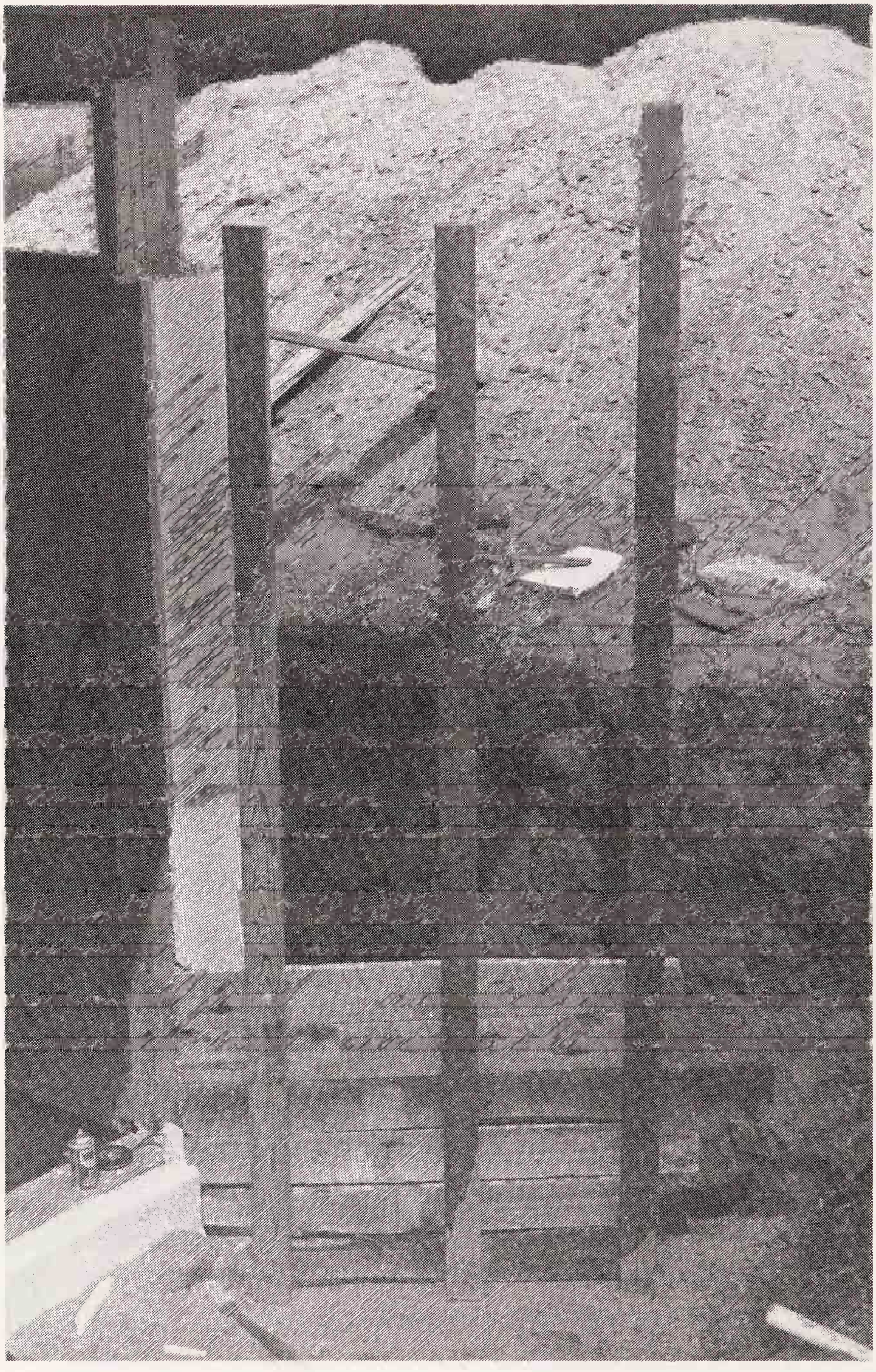


Figure 10-3 Treated posts (imbedded in a concrete footing) can be used to construct an inexpensive retaining wall.

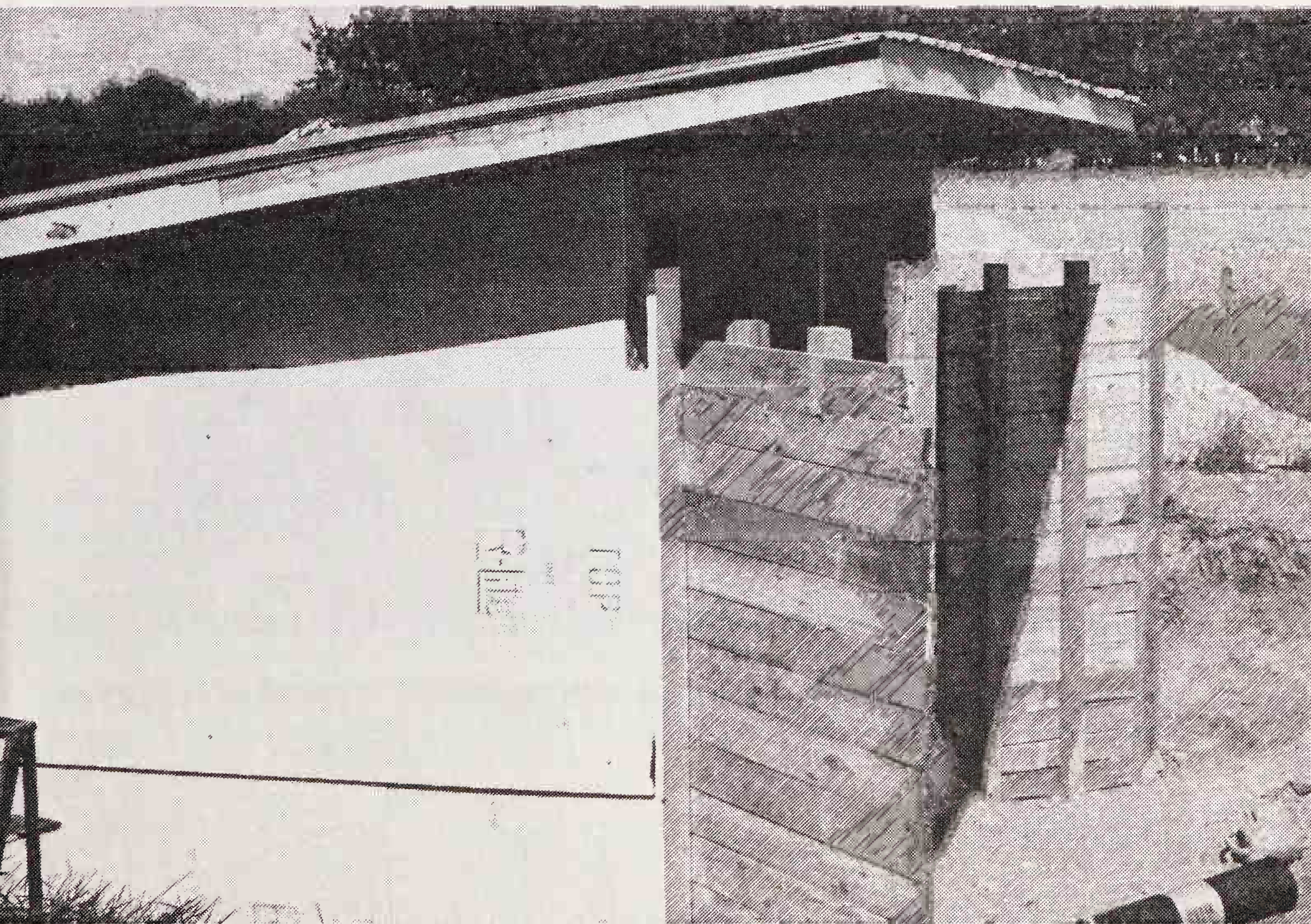
gates quite satisfactorily in an ordinary contractor's wheelbarrow. Making concrete this way is not as inefficient as you might think—especially when you consider how quickly you can clean a wheelbarrow compared to a regular cement mixer. My mixing sequence was the following:

a) five shovels of pit-run gravel
b) add one shovel cement and mix dry
c) add water so that the rock-sand-cement mixture's a little mushy (it mixes easier this way)
d) mix with shovel
e) add one more shovel of gravel to bring the concrete up to the right consistency (stiff, not watery).

When my footing was ready, I put in the three posts, spacing them about eighteen inches apart (see fig. 10-3) and then finished nailing the treated boards to the posts (fig. 10-4).

Finally, I completed the job by "tying" the outer post to the roof framing to make the walls more rigid. I believe that if I were

Figure 10-4 The completed retaining walls with treated boards nailed to the posts.



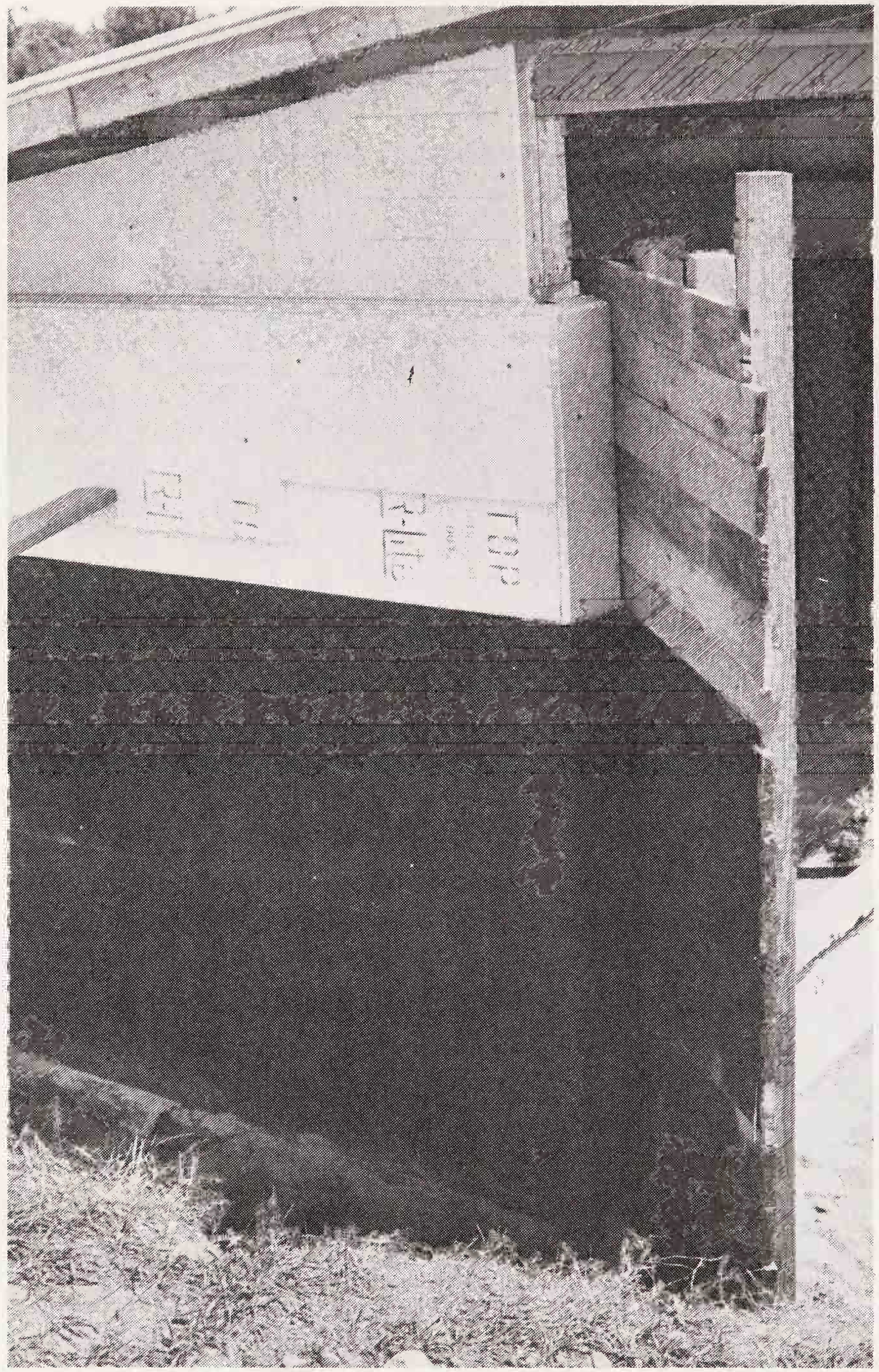


Figure 10-5 The retaining walls (and exterior walls) are covered with 15-pound asphalt felt for extra protection.

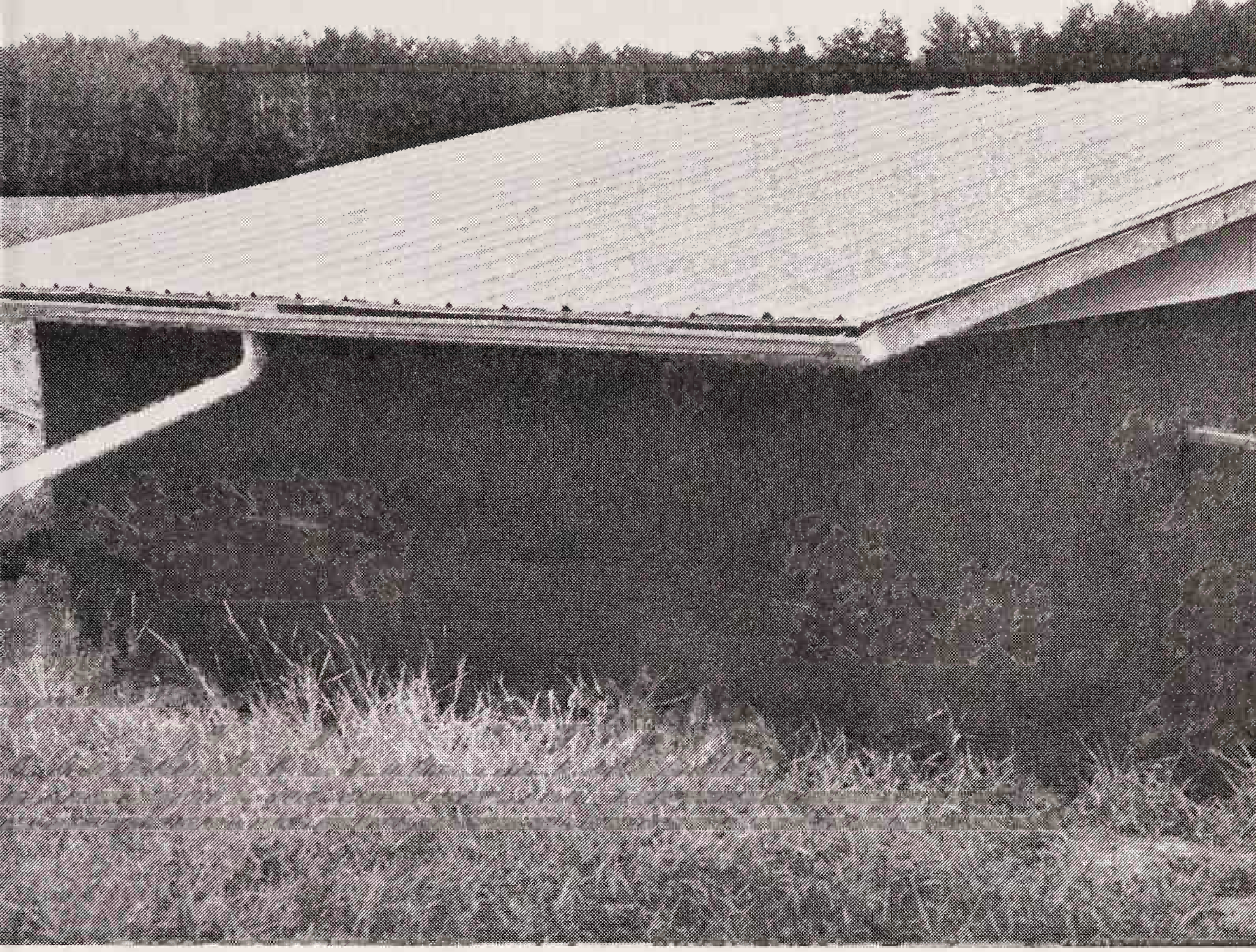


Figure 10-6 With the insulation and felt protection in place, the earth shelter is now completed and ready for backfilling.

going to do it over again, I'd also use the "dead-man" technique of fastening the wall to a concrete pier with steel cables. In addition, I would lag-bolt the inner section of the wall to the 2×6 stud that's fastened to the concrete pilaster. Each of these relatively simple operations would have made the wall that much stronger.

With retaining walls completed, all I had to do now was finish insulating the outside of the concrete shell, afterwhich I would be ready for backfilling. As previously discussed, I used three inches of rigid polystyrene for the top two feet, two inches for the next two feet, and one inch on the bottom four feet. For added protection, I covered the walls (and the inside of the retaining walls) with a layer of 15-pound-asphalt felt—as can be seen in figures 10-5 and 10-6.

Backfilling

In the entire building project, I can only remember two times when I felt an intense, almost overwhelming anxiety. One time was right before I began and the other was "backfilling day."

On that day, inevitable questions loom up in your mind. Will the concrete shell hold? What about the retaining walls—will they tip as if you pushed over a stake in the garden?

There may also be some mental pain associated with the bulldozer itself. It can, indeed, be agonizing to watch one of these machines come snorting in and begin madly pushing dirt around—scraping away at the thin soil, ripping up clover and grass. Although earth-sheltered builders probably cannot avoid the anxiety of this necessary stage, they nevertheless can be fussy about who they bring in for the job. There is, of course, no reason why you could not backfill by hand—except for the time factor. For this project, I needed someone not only to backfill, but also to carve out a large "bowl" in the front. These two jobs demanded experience, care, and respect for the topsoil, plus a dash of artistic skill. To find the right person for this important phase, it pays to look around.

On the morning of the big day, I put in some east/west bracing (fig. 10-7) as suggested by my contractor, Jay Taylor. Soon Jay and his bulldozer arrived, and I simply sat back and watched the show.

All in all, everything went well. No cracked concrete. The retaining walls bent a little in the middle but didn't tilt. And the front bowl was carved out with the craftmanship of a true sculptor. Frankly, I was quite impressed.

For those of you who are building in nonpermeable soils, it'll be necessary to backfill with gravel or sand in such a way as to funnel rainwater into the drainage tile system. Also, in those soils where there may be considerable settling, it is recommended to backfill by slowly watering the soil down and compacting it as you go. Otherwise, the normal settling process may drag down the outside wall insulation.

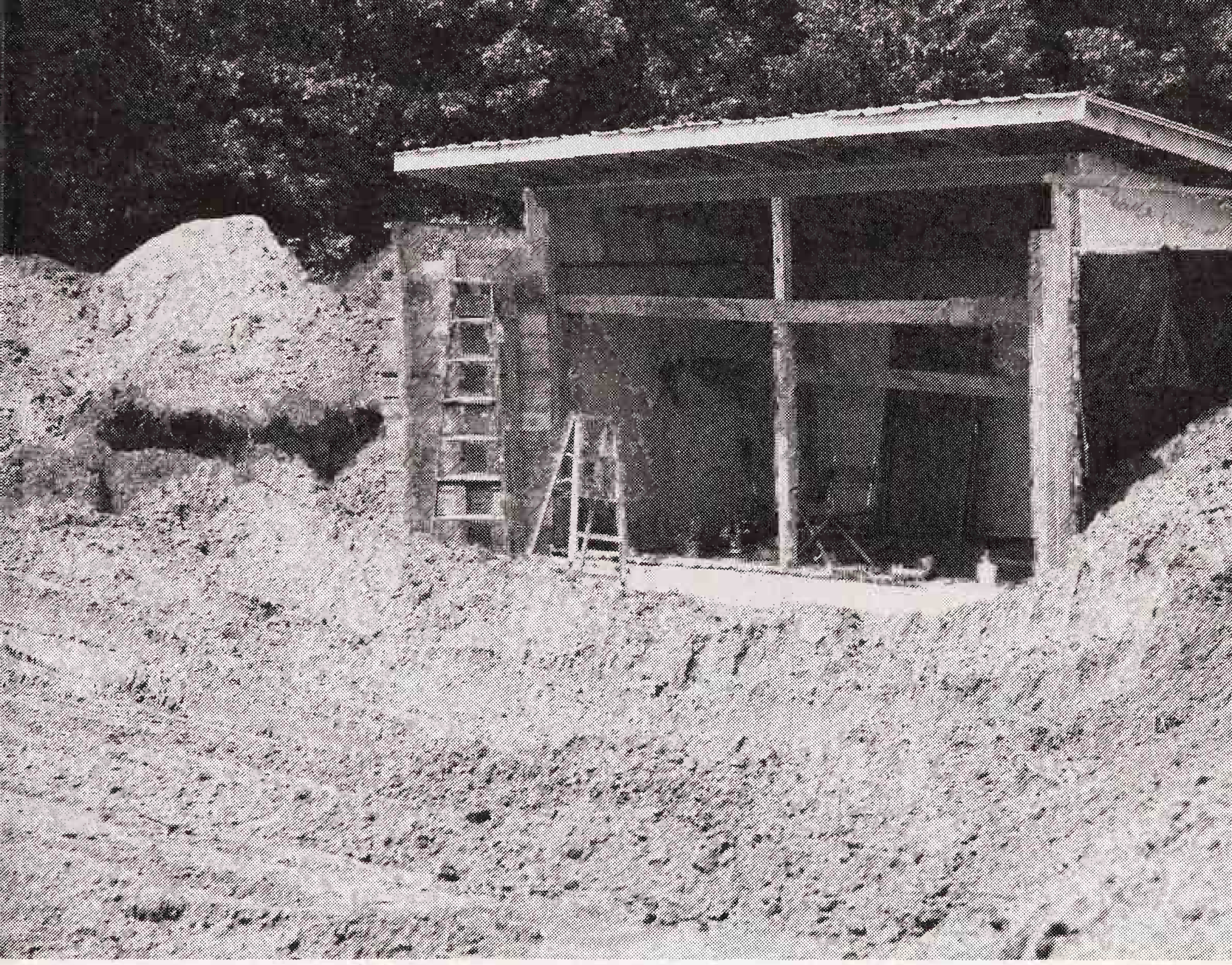


Figure 10-7 Backfilling day—a large "bowl" is carved out in front and the extra dirt is then used to berm up back walls.

The South Wall

Things were now moving along. The one major job ahead was to complete the south wall with a glass door and windows. My original intention was to make this wall as much "thermopane" as possible. But alas, thermopane windows, as you have probably found out yourself, cost plenty. A patio door can run anywhere from $300 to $700 dollars and when I reflected on the fact that my other *three* poured walls cost me *less* than $650, the thermopane patio door began to look like an expensive luxury.

Without any great expectations, I decided to place an ad in our local advertising flyer. These weekly flyers are scrutinized by thousands of readers and are thus a prime resource for the low-overhead builder. And sure enough, I got two calls from families who had taken out their glass doors for one reason or another. My "almost-new" six-foot-wide patio door cost just $85.

I was also fortunate in purchasing three 6′ × 30″ thermopane "seconds" from a friend who regularly visits a factory outlet in a nearby city. Although these windows have a few small scratches (or a little spilled glue), they are otherwise perfectly ok.

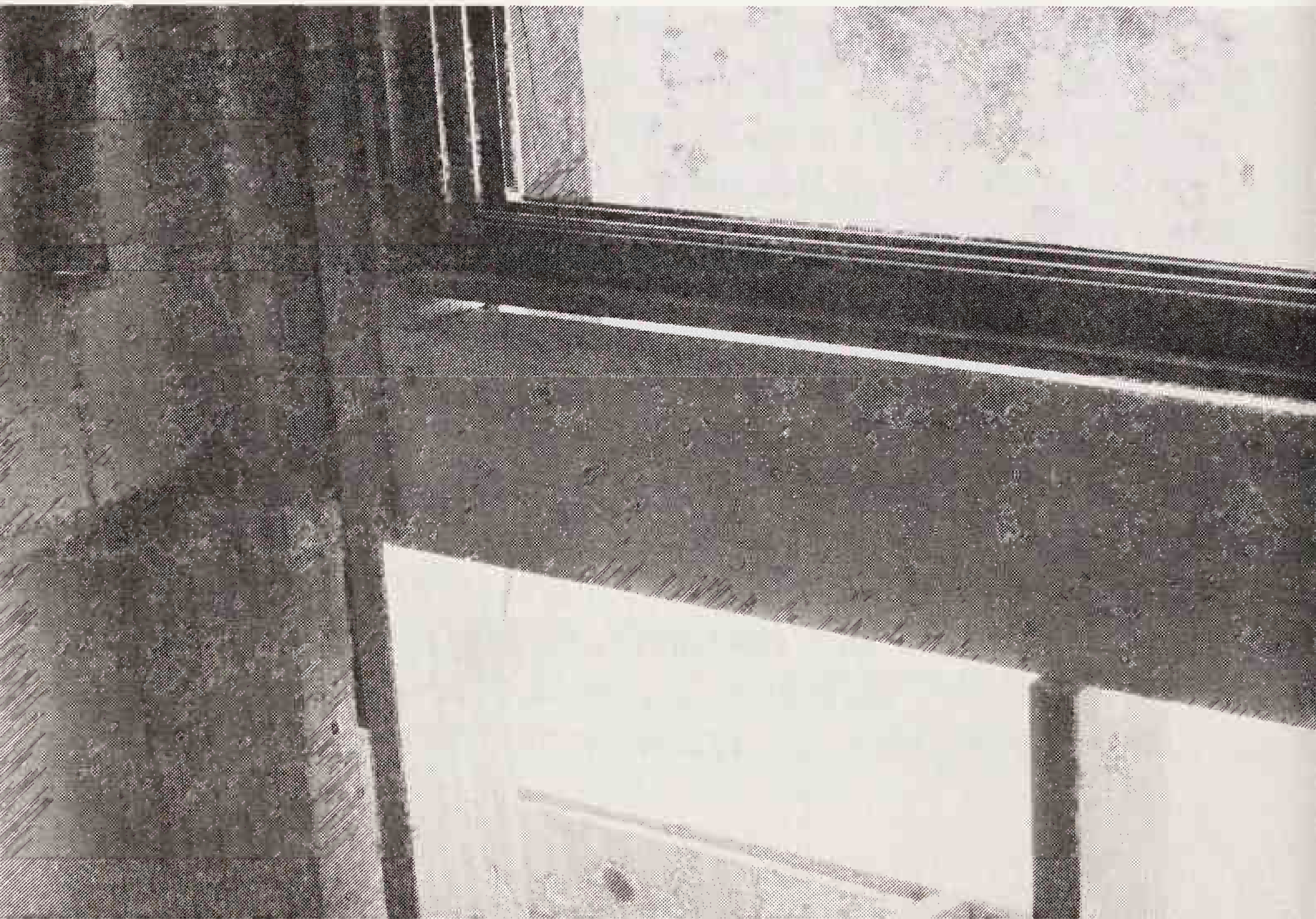
There is nothing particularly difficult about framing for a patio door. You will need a double 2 × 10 "header" (fig. 10-8) above the door to help distribute the roof load onto the studs that are set alongside the door. I did have a problem, however, in figuring out exactly how the door itself was put together.

Since our son Anthony has a genuine knack for jigsaw puzzles, I asked him for his assistance: by mid-day the two of us had it figured out. You can see the installed door and also the completed south wall framing in fig. 10-9.

Also note the rigid insulation "shelf" in the front. I placed the shelf next to the two inches of polystyrene that insulates the front footing. I then angled the pieces down and away from the building to keep moisture away from the footing.

Afterwards, I covered the shelf with about three inches of dirt. These procedures—including the insulation of the footing

Figure 10-8 **A double 2″ × 10″ header above the patio door distributes the roof load onto the studs alongside the door.**



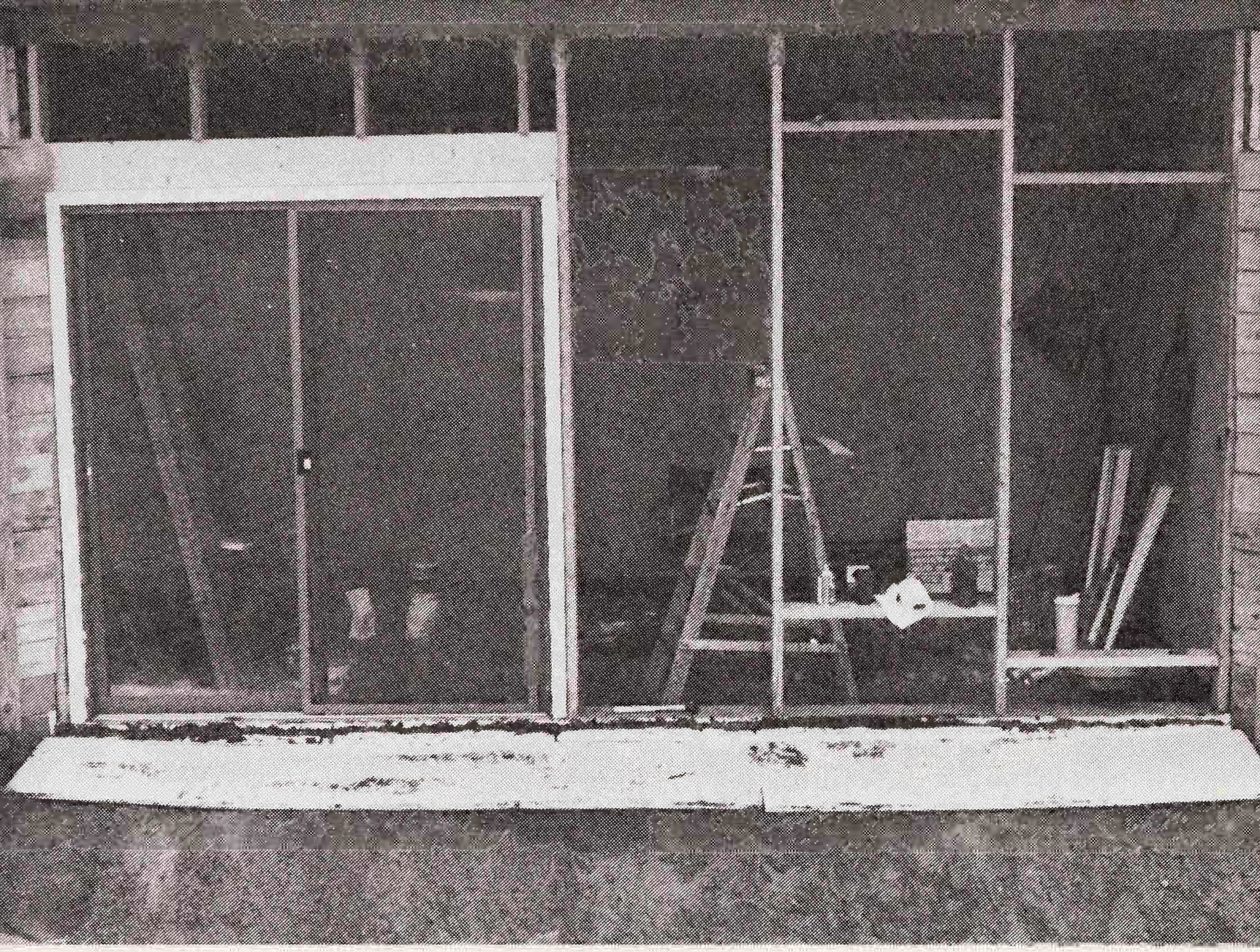


Figure 10-9 **A shelf of rigid polystyrene angled down and away from the south wall protects the front footing from moisture, freezing, and thawing.**

itself—are extra insurance against the potential frost heaving problem discussed earlier.

In framing the windows, I wanted to make sure that no edge of the glass would be touching wood. Thus I took pains to allow a quarter inch or so leeway on all sides. For the window bottom, I cut an old innertube and stapled three layers down onto the sill. One of these small rubber cushions can be seen in fig. 10-10.

Next, I tacked an inexpensive 1×2 inch "moulding" board onto one side of the framing (all the way around), then carefully lifted the large pane into place. As I tacked on the outside moulding, I again made sure that there was a quarter inch of air space on each side to allow the window to rock back and forth gently within its frame. Finally, I filled in the space with silicone caulk. In the end, no glass would be touching any part of the wood framework. The thermopane can thus expand and contract without any risk of cracking or breaking its seal.

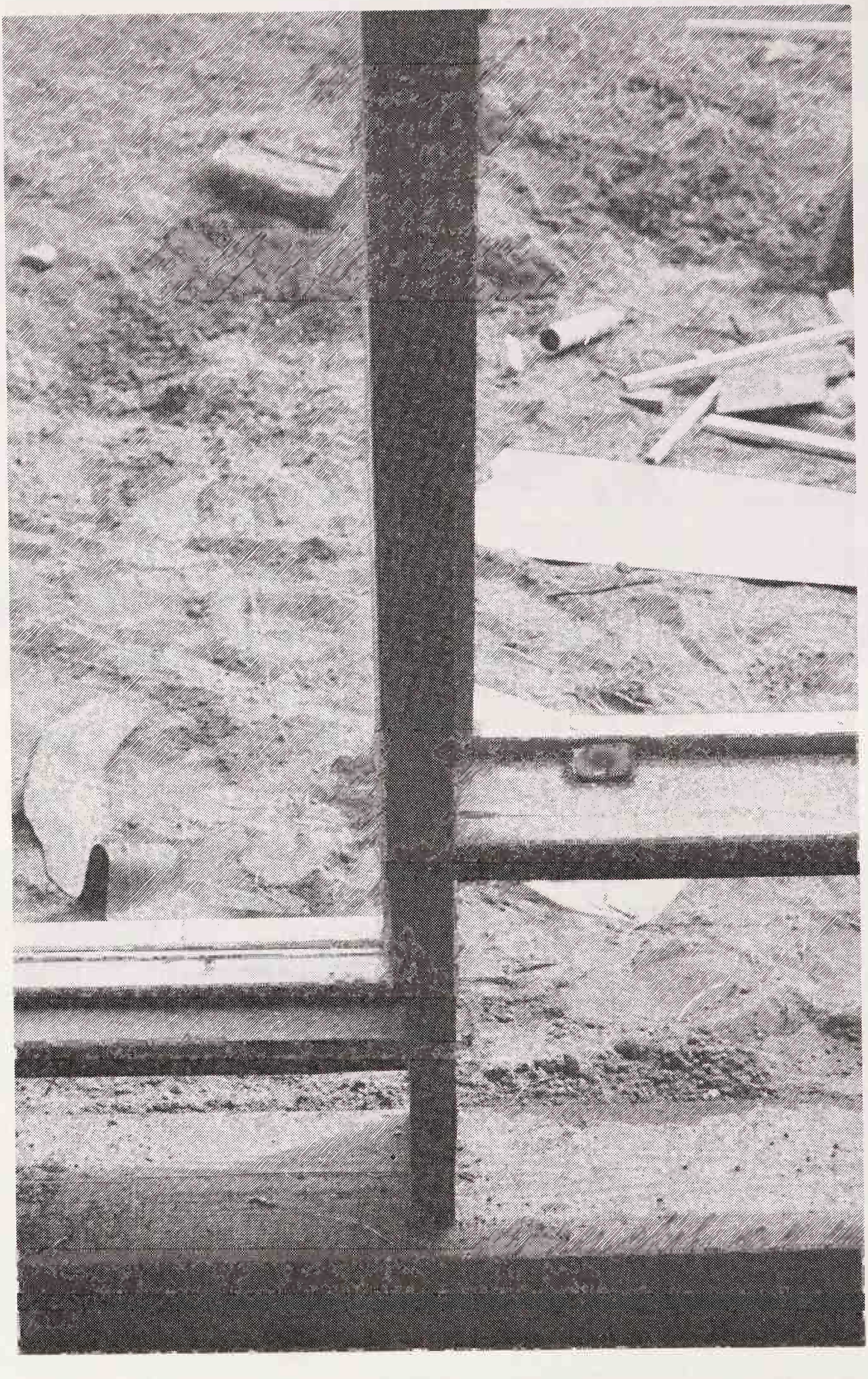


Figure 10-10 A small rubber cushion keeps the window glass from touching the wood frame and eliminates the risk of cracking through contraction and expansion.

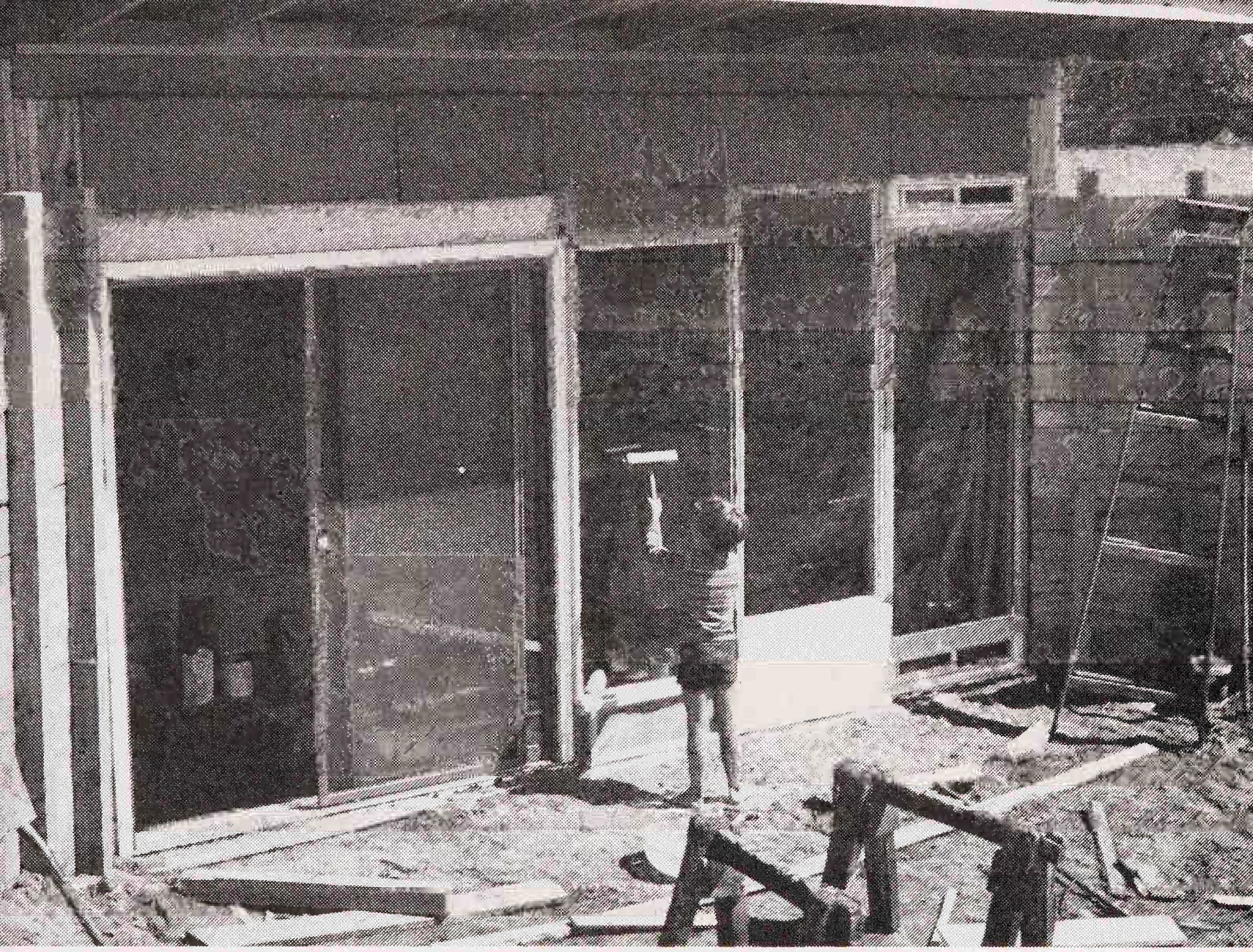
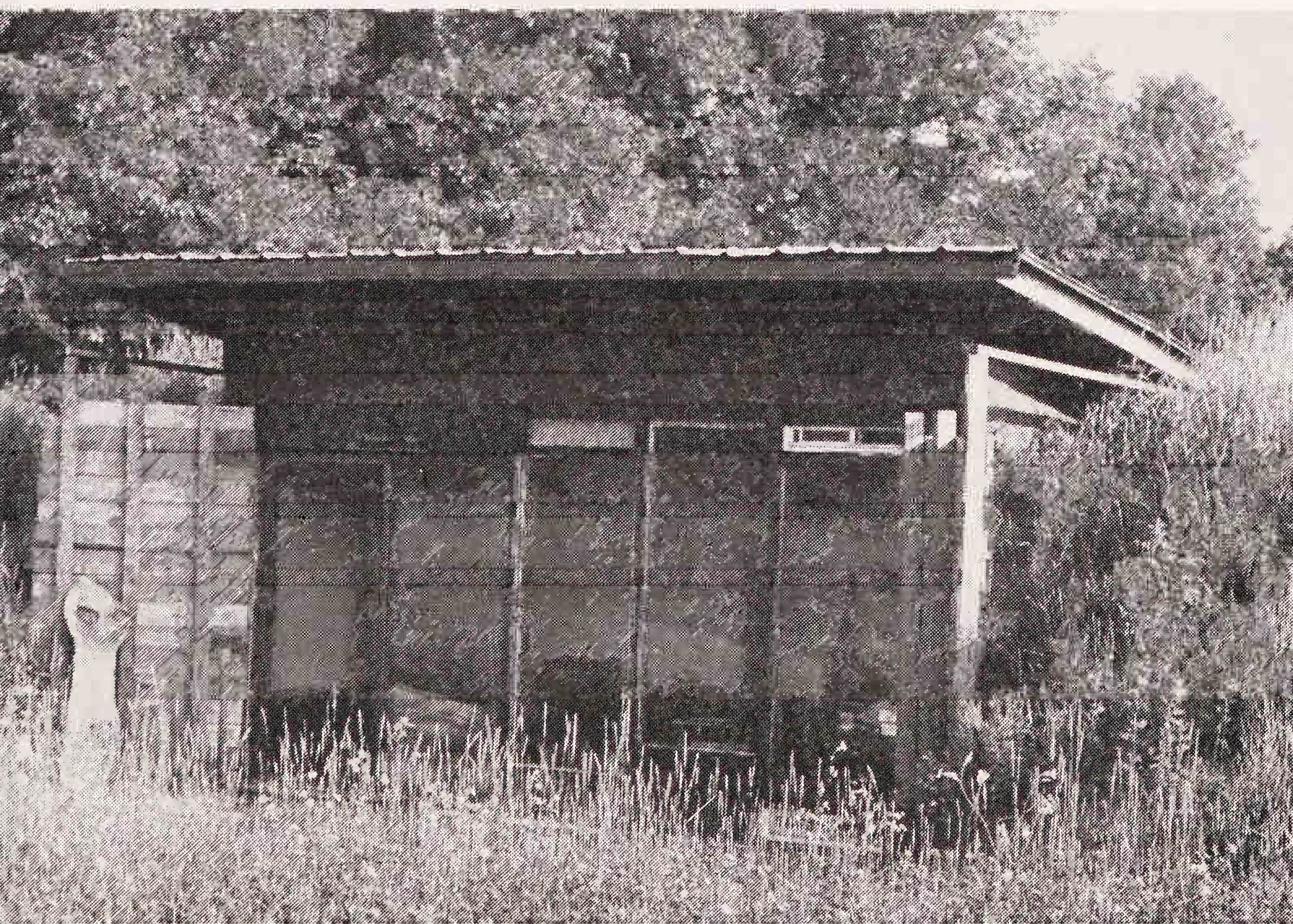


Figure 10-11 The south wall almost complete: one of the remaining tasks is cleaning the windows.

Figure 10-12 Surrounded with wildflowers and grasses and sheltered by earth, the office workshop is completed.



When the south wall was complete, we had a strong urge to clean the windows (fig. 10-11) and then go inside this "subterranean" building and enjoy the wide view of the earth in front, the trees in the background, and the sky and clouds above.

Of course, there were still lots of minor details left to do: vents and covers had to be made and my upper triangles still had to be insulated and finished off. In addition the upper parts of the front had to be filled in with fiberglass, covered, and painted. Before winter, I would also install a wood stove and an "all-fuel" chimney. But these tasks would not take long, nor present any unusual difficulties.

My little workshop was in fact pretty much complete. Eventually with grasses and wild flowers surrounding it, the building would become less and less obtrusive as it slowly began to blend into the environment.

Chapter 11

Evaluation and Conclusion

> "Some of our friends and neighbors cry out in protest: 'But the lines on these old houses,' Our answer is simple . . . If we are worth a snap of the fingers, we can build with lines as good or better than our great grandfathers. If we cannot, we do not deserve to live in a well-designed house."
>
> Helen & Scott Nearing

Thermal Efficiency

You can make no argument so convincing, so persuasive for the earth-sheltering principle combined with passive solar energy, as when you invite a friend over on a bitterly cold, but sunny day.

Of course your visitor will immediately notice the pleasant air temperature and the relatively warm floor. But the real clincher comes when he goes over to the wood stove, puts his hand on its surface, and discovers—it's cold!

More specifically, the temperatures in my office/workshop during the three months of December, January, and February ranged from slightly below freezing to the high eighties. This is in contrast to an outside temperature range of minus 22°F to a plus 46°F for the same period.

I was thus pleasantly surprised with the building's general comfort level, and the high daytime temperatures resulting from its passive solar design. On the other hand, I was somewhat disappointed that its concrete mass was not capable of holding solar heat for more than a few hours after dark. Originally I had hoped for perhaps a day or so of solar heat storage. The problem was not in the sun's intensity, nor in its coverage, but was more because of the relatively *brief* period (say four hours per day in January and February) that the sun came into effective contact with the floor and walls. There was simply not enough time to raise the temperature of the large mass sufficiently for long-term solar comfort.

However on those dull overcast days, when I did use my wood stove and insulated panels, and when the walls and floor were allowed to heat up over a longer period of time, the building then continued to be comfortable into the next day without any additional heat. I might add that it is a surprisingly pleasant sensation to have radiant heat coming at you from the surrounding walls and floor.

Keep in mind too that earth-bermed concrete is always at or near the relatively warmer subterranean temperatures. It thus takes significantly *less* heat to bring the temperature up to a comfortable level. All in all, the above thermal advantages plus the natural cooling factor in the summertime make this ''concrete-wall, earth-bermed-passive-solar'' design a good one in terms of thermal efficiency.

Waterproofing Effectiveness

The other important requirement in underground or earth-sheltered buildings is the efficiency of your waterproofing. In fact, you could rightly argue that if your subterranean shelter fails the moisture test, all its earth berming and passive solar advantages won't mean much.

As mentioned earlier, I reduced my potential moisture problems by: a) building in sand, b) using a conventional roof, and c) by partial berming (instead of going completely below grade). In addition, I built long overhangs and dampproofed my walls with a water resistant paint. So far, there has been no noticeable dampness or moisture infiltration through my walls. Even during a heavy six inch rain (over a three day period), I had no problem except for a small leak in the stovepipe flashing. In addition, I was pleased to find that even after these heavy rains, the dirt next to the wall remained dry.

Yet early on I did have a water problem in the front. Recall that my office is some four feet below grade. There would therefore be a tendency for water to accumulate in the "bowl" area—especially after a short, hard rain. During one particularly bad storm, runoff water filled this earth cavity and came within a couple inches of my front sill-plate.

It's interesting to note how quickly one learns about the "natural laws" of hydraulics under such circumstances! In the case above, I noticed that most of my problem was the large amount of water draining in from an area northwest of the building. This uninvited stream was easily rerouted around the upper lip of the bowl by a forty-foot-long ditch.

To accommodate the rainwater that would inevitably accumulate at the bottom of the bowl, I installed a simple barrel-rock "drywell." I first dug a hole 3 feet wide and 4½ feet deep using a post-hole digger. Next, I found a barrel, took out the bottom, and punctured the wall with dozens of small holes. Completing my material requirements, I bought a pickup load, or about one and a third yards of 1½ inch "drainage field" stone from a local gravel plant.

I lowered the barrel into the hole, filled it up with rock, and spread the surplus gravel around the drain. Finally, (as can be seen in fig. 11-2), I made a barrier out of a piece of metal roofing

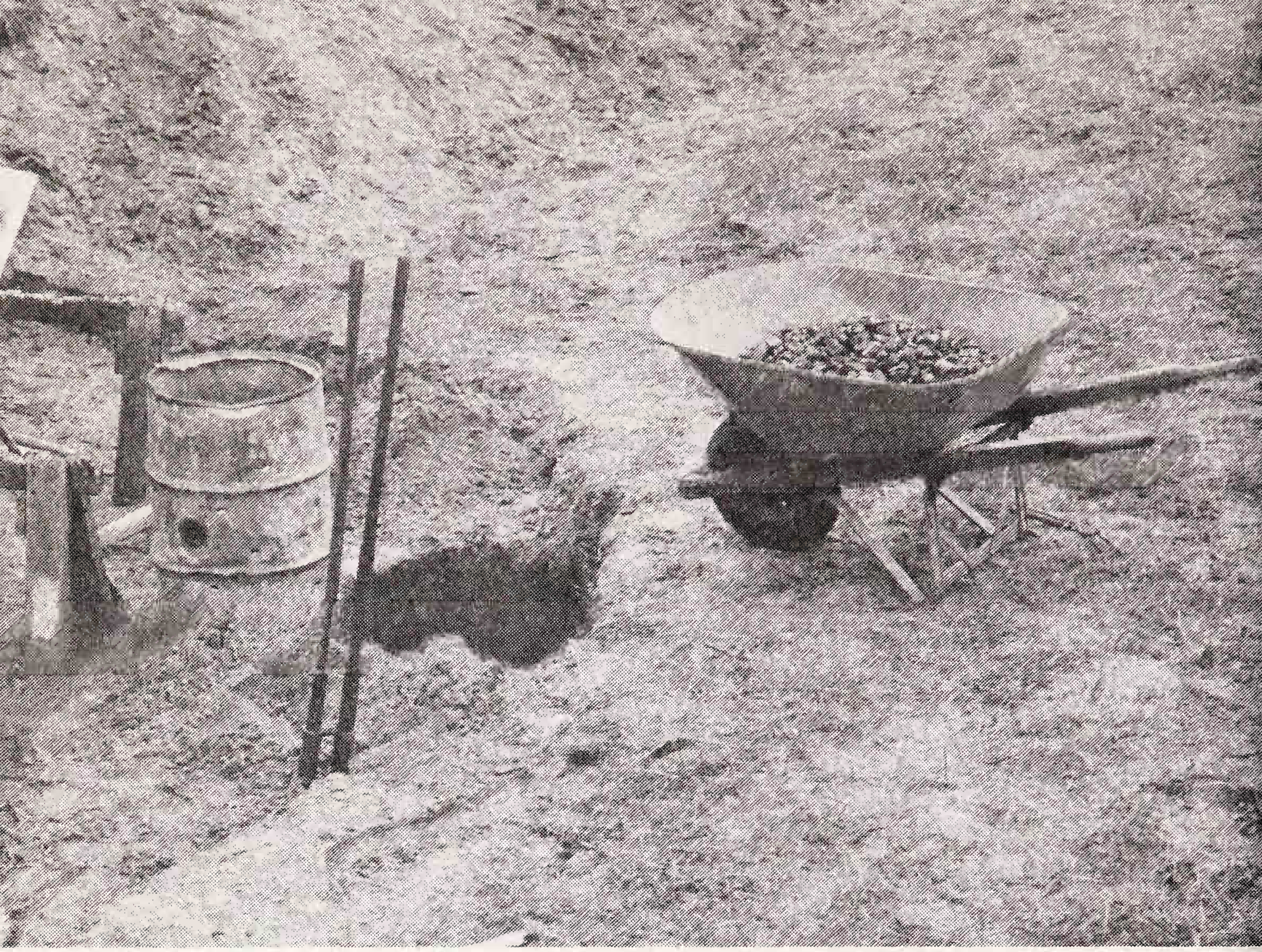


Figure 11-1 The solution to a water runoff problem: a simple drywell made with an old barrel and drainage field stone.

to block dirt that might erode down from the hill into the drainage area.

This inexpensive drain works remarkably well. For example, during the six inch rain of June 1980, I found no standing water in or around the drainage area. However a good drywell in front will not necessarily prevent water problems during the spring thaw. Especially when the frost is unusually deep, the drain itself might also be frozen. If this happens, you may well need the temporary services of a sump pump during this brief, but critical period.

In summary then, the experimental office/workshop has (so far) worked out well. In the crucial areas of thermal efficiency and waterproofing, I've been generally satisfied. The other important factors of natural lighting and ventilation (discussed in chapter 7) have also met my original expectations. So far, so good.

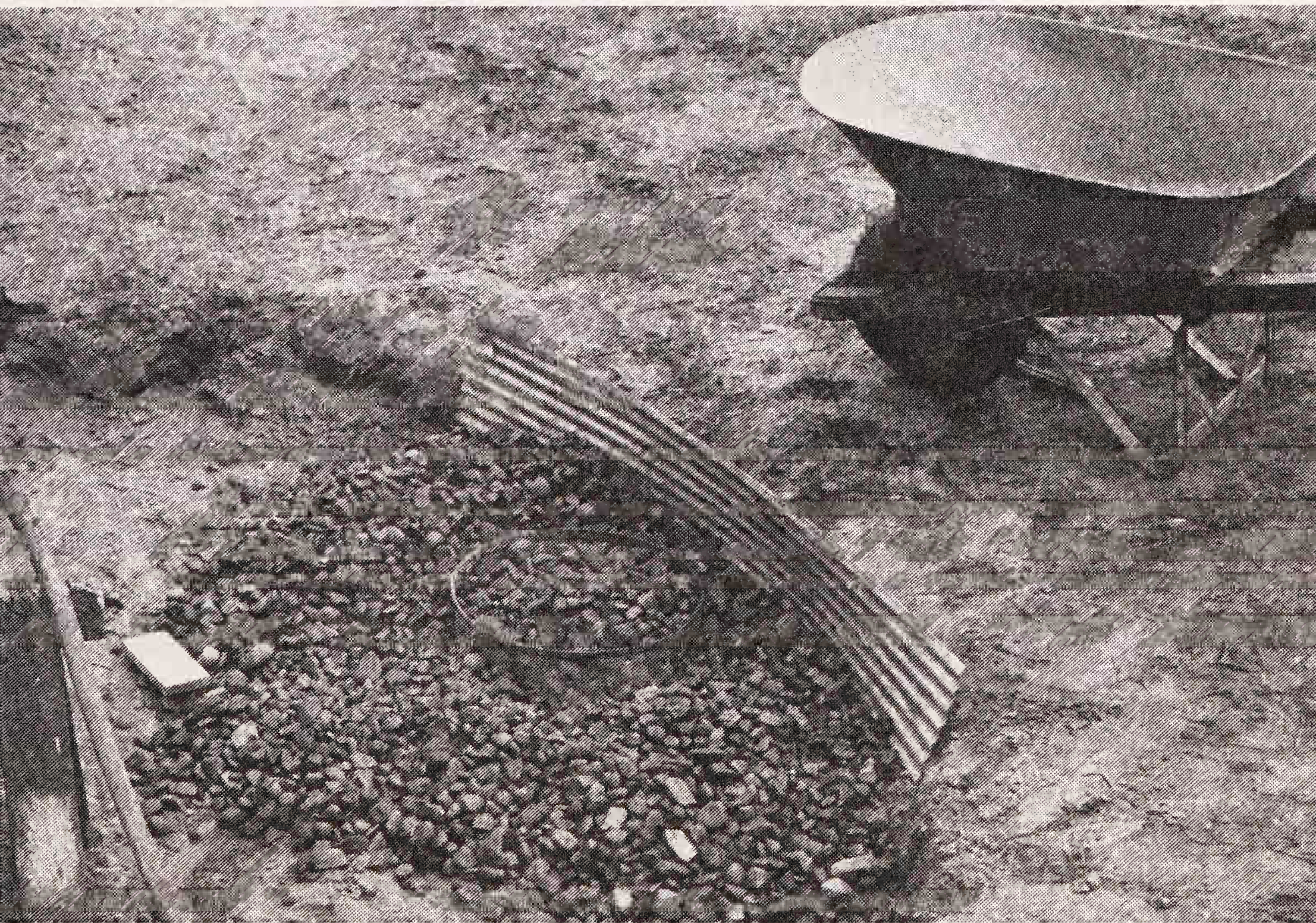
But what about your project? I would hope that you feel free to use any of these concepts that might fit into your own earth shelter plans. On the other hand, I would also encourage you to forge ahead with *your own* ideas, pet theories, and individual building experiments. Owner-built construction is a very personal art—and it needs, I think, a wide latitude to express itself. I would therefore like to conclude with a few brief thoughts concerning this vital freedom—the "freedom to build" and its relationship to the growing power of building codes.

Freedom to Build

Surely one of the greatest potential problems for the low-cost owner/builder is the increasing use and misuse of city and, in some cases, statewide building codes.

Admittingly, we *do* need some protection for the average housing consumer—protection mainly from unscrupulous building contractors who, in their zeal to make a fast buck, may at times bypass minimum safety standards.

Figure 11-2 The barrel is installed and filled with rock. A piece of metal roofing forms a barrier to prevent erosion into the drainage area.



Furthermore, plumbing codes are often necessary to insure public sanitation, and electrical codes are advisable to minimize the danger from electrical fires. There is little argument that these two vital components of modern housing do need some kind of public scrutiny—particularly in heavily populated areas.

In addition, I believe that owner/builders should take advantage of the existence of comprehensive building codes. In studying the codes, he or she will find that these publications are rich in information pertaining to building safety, structural and insulation efficiency for their particular area.

But having said this, I also feel that society should provide places and opportunities for people to build as they choose, to construct practical and economical dwellings as their instincts dictate without the coercive power of the state looking over their shoulders. Society ought to provide this climate for building freedom not just for personal economic reasons either.

Don't we all, at least indirectly, benefit from the inventions and innovations of these do-it-yourselfers? Indeed, it's often dispiriting to learn of well-meaning legislation that may well have the effect of inhibiting those individuals who value hard work, and who will respect and learn first hand the natural laws as they pertain to home construction—the nature of wood and concrete, structural integrity, thermal efficiency, sunlight, ventilation, and so forth.

Perhaps in no other single project in our lives can we learn so many truly important and practical things. Building forces us into an objective pragmatism—we see exactly what works and what doesn't; and in our failures and successes, we begin to understand that there is a kind of ''organic truth'' to materials and processes. ''Everything that happens,'' said Marcus Aurelius, ''happens as it should and if you observe carefully, you will find this to be so.'' Shouldn't society *encourage* people who value this elevated pragmatism?

I profoundly believe that building codes—especially those that are rigid and specific, and couched in punitive language, have the effect of *dissipating the enthusiasm* of beginners who might have become owner/builders. Strict codes mean that the long arm of the law will be with you as you build, watching, watching, and at times, dictating how far your nails are to be spaced, how large your floor joists must be, the size of your windows, and so forth. Any deviation, and an inspector may force you to do it over. And much, of course, will depend on the personality and integrity of the individual inspector.

Often a statewide uniform code will insist that builders submit complete working-drawings *before* they can be issued a permit to build. This requirement may sound logical. In fact, most conventional builders would have no problem going along with it.

Yet, an architect's working-drawings are an extra expense, and will also have the effect of reducing the freedom to *improvise*—a process common among owner/builders who are learning as they go. There will be the mandatory visits from the inspector making sure that everything is up to the original design—watching, watching. I hold that this can only have a chilling effect, eliminating the freedom to learn by making mistakes, or possibly to chance upon an unlikely, but useful, innovation.

Perhaps the advent of regional building codes may have the unfortunate effect of encouraging individuals to disobey the law, to go ahead with their projects (in the spirit of Thoreau, Gandhi, and King)—in defiance of codes and inspectors. It is surely an issue that is bound to be abrasive. A good book that describes these problems is *The Owner-Builder and the Code—Politics of Building Your Home*.[23]

I repeat that society should not discourage owner/builders, but encourage them. To improve the climate for building freedom, legislators might pass ''owner/builder amendments'' that eliminate the more coercive aspects of the mandatory code and inspector system.

As a more positive approach, I might suggest that we utilize our inspectors not as ''Big Brothers,'' but use them more along the lines of county agricultural agents. As you probably know, the county agent is the person *you call* when you have questions or a specific problem about farming. He is armed with a variety of government publications to help the farmer do his job. If need be, the agent will come out at no charge and inspect the farmer's corn blight, soil quality or some other aspect of his operation about which he may have questions.

Now in that same office with the agricultural agent, why couldn't there by a "county building agent" (former inspector) who can offer the same kind of courteous and expert services to the amateur home-builder? The County Extension Service has been an immensely successful program, indeed a popular program since 1914. Is there any reason we could not apply the same principle to builders? Unfortunately it seems difficult for legislators to understand that there are light-years of difference between the coercive system of the code-inspector and the system of county-agent-as-a-resource.

Of course this idea of well-meaning government laws that have the effect of inhibiting freedom and innovation is not new. It can be traced at least as far back to the stifling guilds and the stagnation of the Middle Ages. Yet, whenever the long arm of government rigidly regulates those private areas of endeavor, it can hurt not only individuals, but it can also violate man's unique evolutionary spirit—a spirit that needs wide latitude to learn by making mistakes.

In a broader biological perspective, I think Lewis Thomas was right when he observed that our ability to "blunder" is the real marvel of our uniqueness.

> We are at our human finest, dancing with our minds, when there are more choices than two. Sometimes there are ten, even twenty different ways to go . . . and the richness of selection in such a situation can lift us onto totally new ground. This process is called exploration and is based on human fallibility. If we had only a single center in our brains, capable of responding only when a correct decision was made, instead of the jumble of different, credulous, easily conned clusters of neurones that provide for being flung off into blind alleys, up trees, down dead ends, out into blue sky, along wrong turnings, around bends, we could only stay

> the way we are today, stuck fast, The lower animals do not have this splendid freedom. They are limited, most of them, to absolute infallibility. . .[24]

In conclusion, I profoundly believe that we need to preserve those freedoms that allow us to make mistakes, to learn, and finally to enjoy our inventions and successes—in short, freedom to proceed at widely different angles. Building your own shelter is surely one of these fundamental freedoms.

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4. Ken Butti and John Perlin, *A Golden Thread; Twenty Five Hundred Years of Solar Architecture and Technology* (Palo Alto, CA: Cheshire, 1980), p. 5.

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8. Robert Roy, ''Earth-Roof Thickness; The Tradeoff,'' *Earth-Sheltered Digest,* Jan./Feb. 1981, pp. 16–19.

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14. Ken Kern, Steve Magers, and Lou Penfield, *The Owner Builder's Guide to Stone Masonry* (New York, NY: Scribner's Sons, 1976), p. 157.

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17. Mike Oehler, *The $50 and Up Underground House Book*, p. 82.

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19. Nearing, *Living the Good Life*, p. 45.

20. B. Carl Haynes, Jr. and J. W. Simons, ''Construction with Surface Bonding,'' USDA Agriculture Information Bulletin #374, (Washington, D.C.: Government Printing Office, 1974), p. 3.

21. Pat and Jim Eggert, *The No-Mortgage Home* (Colfax, WI: Bergamot Press, 1973).

22. Rex Roberts, *Your Engineered House* (NY: M. Evans and Company, 1964), p. 58.

23. Ken Kern, Ted Kogan, and Rob Thallon, *The Owner Builder and the Code - Politics of Building Your Home* (Oakhurst, CA: Owner-Builder Publications, 1976).

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Appendix 1

Further Reading

Self-Reliance and Low-Overhead Philosophy

If you want further encouragement on becoming more self-reliant, read *Walden* by Henry Thoreau. It's America's original inspiration on why we should (and can) live simply and wisely. In particular, see chapter 1, "Economy."

A modern classic on low-overhead living that includes a detailed description of building with stone using the slip-form method is Helen and Scott Nearing's *Living the Good Life* ($4.95 postpaid from Schocken Books, 200 Madison Ave, New York, NY 10016).

The best single source of where to find resources for living a self-reliant life is *The Next Whole Earth Catalog* ($14 postpaid from Whole Earth Household Store, Building D, Fort Mason Center, San Francisco, CA, 94123). This 608-page book is a complete updating of Stewart Brand's original award-winning "access to tools."

Earth-Sheltered Housing

The original earth-sheltered standard, the book that first got people excited about underground housing, is the Underground Space Center's *Earth Sheltered Housing Design* ($10.95 from Van Nostrand, 7625 Empire Dr., Florence, KY 41024). It still remains an excellent reference book covering all major factors dealing with earth-protected housing.

An interesting book to order for your library is *The Use of Earth Covered Buildings* by The National Science Foundation ($5.25 postpaid from The Superintendent of Documents, U.S. Govt. Printing Office, Washington, D.C. 20410). This book contains a series of papers from a 1975 conference held in Ft. Worth Texas. There's a wide range of discussion on almost every aspect of earth-sheltered buildings—from historical applications to future possibilities. Very general. Among those who submitted papers are Ken Labs, Malcolm Wells, and Tom Bligh who have all written their own pioneering books and articles on the subject of underground housing.

Well's book, for example, is *Underground Designs* ($6 from Malcolm Wells, Box 1149, Brewster, MA, 02631). Lovely architectural designs from one of the early advocates of underground living, but unfortunately quite expensive to build (compared to our low-cost approach).

A good book to read early on before any major decisions have been made, is *The Earth Shelter Handbook,* by Tri/Arch Associates, ($12.95 postpaid from "Mother's Bookshelf," P.O. Box 70, Hendersonville, NC 28791). Though the writing style seems to be somewhat fragmented, there is valuable material here on subjects such as soil types and the pros and cons of different foundations (wood, concrete, concrete block, steel culvert, etc.).

Described earlier in chapter 3 and highly recommended is Robert Roy's *Underground Houses* ($7.00 postpaid from Sterling Publishing, 2 Park Ave., New York, NY 10016 or from the author at RR1, Box 105, West Chazy, NY 12992). Also if you are thinking of going the inexpensive "pole approach," be sure to get Mike Oehler's *The $50 & Up Underground House Book* ($9.95 postpaid from Mole Publishing Co., Rt. 1, Box 618, Bonners Ferry, Idaho 83805).

In the same category of the above *Earth Sheltered Housing Design*, I'd also recommend Stu Cambell's *The Underground House Book* ($9.95 postpaid from Garden Way, Charlotte, VT 05545) Comprehensive and quite readable. Also a nice survey of existing underground houses—giving you that positive feeling that going earth-sheltered is not such an oddball thing to do anymore.

As I mentioned in the text, don't overlook the U.S.D.A. Soil Conservation Service's *Soil Surveys*, often available at your county soil conservation department. These surveys contain complete soil maps and the descriptions of dozens of soil types. Although specifically designed to help farmers, they can also be used to aid you in site selection for earth-sheltered houses.

Earth-Sheltered Resource Materials

Readers interested in surface bonding techniques with block walls should write for *Construction with Surface Bonding* by the U.S.D.A. Agricultural Research Service. It's Bulletin No. 374, Stock No. 001-000-03340-9 (45¢ from Superintendent of Documents, U.S. Govt. Printing Office, Washington, D.C. 20410). Free from Bonsal Co. (P.O. Box 38, Lifesville, NC 28091) is *How to Build With Surewall-Surface Bonding Cement*. Ask for the pamphlet and also for the nearest dealership in your area. Also without charge is the brochure *Fiberbond Construction Techniques Manual*—FC TM-2197 (from Stone Mountain Manufacturing Co., Lafayette Center Suite 304, P.O. Box 7320, Chesapeake Blvd., Norfolk, VA 23509).

If you are considering treated wood foundations, for $5 you can get *All-Weather Wood Foundation System-Design, Fabrication, Installation Manual* (National Forest Products Association, 1619 Massachusetts Ave., N.W., Washington, D.C. 20036) which goes into considerable detail (often fairly technical) of "all weather" wood basements. Particularly useful is their section on the "dry basement design."

Free from the Portland Cement Association (Old Orchard Rd., Skokie, IL 60076) is *A Critical Evaluation of Plywood Basements and Wood Foundations*. Since this booklet was prepared by those who have a vested interest in concrete foundations, you should realize that it will be somewhat biased. Nonetheless, there are certain criticisms raised that ought to be carefully considered by those contemplating a treated wood foundation. For those readers who want to review the research on the hazards of both arsenate and penta wood preservatives, write for *Wood Preservative Pesticides* Federal Register, Vol. 43–No. 202, 10-18-78, Book 2; from Superintendent of Documents, Govt. Printing Office, Washington, D.C. 20402).

Considering a stone foundation? First read *The Owner Builder's Guide to Stone Masonry* by Ken Kern, Steve Magers, and Lou Penfield ($12.20 postpaid from Charles Scribner's Sons, Vreeland Ave., Totowa, NJ 07512). It covers all important aspects of building with stone—from gathering to laying and forming. Especially of interest to those considering the slip-form method is a detailed description of how to build a "modified Magdiel" steel form, a durable, lightweight alternative to moveable wood forms.

As mentioned in chapter 4, two good books on how to use wooden slip-forms are *Build Your Own Stone House* by Karl and Sue Schwenke ($5.95 from Garden Way, Charlotte, VT 05445) and the Watson's *How to Build a Low-Cost House of Stone* ($6 postpaid from Stonehouse Publications, Box 4101, Sweet, ID 83670). See text for more information.

Most conventional waterproofing materials (paints, black plastic, mastic, etc.) can be obtained from local building supply houses. But if you're looking for information on bentonite, you may have to write for it. I would suggest writing Effective Building Products Inc. (2950 Metro Dr., Suite 305, Minneapolis, MN 55420). They are a reliable supplier for spray and do-it-yourself trowel-grade bentonite. A long-time manufacturer of bentonite kraft boards is the American Colloid Co. (5100 Suffield Court, Skokie, IL 60077). Ask for their free brochure on Volclay Panels. Also, your local well driller may be a good source for obtaining bentonite. Worth checking out in your area.

The only magazine that is exclusively oriented to the interests of earth-sheltered builders is *Earth Shelter Digest and Energy Report* ($15/yr from Webco Publishing Inc., 479 Fort Rd., St. Paul, MN 55102). After a slow start, this periodical has come into its own . . . now offering excellent articles on a wide variety of subjects related to earth-sheltered housing. Highly recommended.

Another good magazine (which frequently covers earth-sheltered projects) is Rodale's *New Shelter.* One thing I like about *New Shelter* is its wide range of subject matter—from housing philosophy (including a surprising emphasis on small, low-cost houses) to the specific how-to-do projects. I also appreciate their "Product Reviews" which give actual test results of brand name products (similar to *Consumer Reports*). Nine issues per year for only $10 (write New Shelter Magazine, Emmaus, PA 18049).

Books on Solar and Alternative Energy

Out of a wealth of books on energy efficiency, one of the best is Eugene Eccli's *Low-Cost, Energy-Efficient Shelter* ($7.95 from Rodale Press Inc., 33 E. Minor St., Emmaus, PA 18049). Here you will find practical instructions on all kinds of energy related projects while keeping a careful eye on cost-effectiveness. A good buy on solar energy is the *Sunset Homeowner's Guide to Solar Heating* ($3.95 from Lane Publishing Co., Willow & Middlefield Rds., Menlo Park, CA 94025). Earth-sheltered builders have, of course, a special interest in passive solar. Perhaps the best book around on this subject is *The Passive Solar Energy Book* by Edward Mazria ($14.95 from Rodale Press Inc., 33 E. Minor St., Emmaus, PA 18049). It does a wonderful job of simplifying the principles and then applying them to typical housing situations.

Looking for some good alternative energy magazines? I would recommend first of all *Alternative Sources of Energy* ($15/yr. from ASE Inc., 107 S. Central Ave., Milaca, MN 56353). It's an excellent little magazine that covers recent developments in wind, solar, and wood technologies. Also, every so often, they have a special issue devoted to earth-sheltered housing. Then, of course, there is *The Mother Earth News* ($15/yr from MEN P.O. Box 70, Hendersonville, NC. 28791). "Mother Earth" is one of those few magazines where one can sit down to read (any issue), and become absorbed in some fascinating project of one of their contributors. It never fails. And when we read about so much going on "out there," we cannot help but become a little more optimistic about the future. Also, I've found "Mother's Bookshelf" (same address) to be a reliable source of alternative life-style type books including many of those mentioned in this Appendix.

Books on General Construction

Perhaps the best "general idea" book on low-cost shelter is Ken Kern's *The Owner-Built Home* ($9.20 postpaid from Charles Scribner's Sons, Vreeland Ave. Totowa, NJ 07512). Also lots of good information on tools and salvaging. One of the most highly recommended books on general carpentry is Willis H. Wagner's *Modern Carpentry* ($13.28 postpaid from Goodheart Wilcox Co., 123 W. Taft Dr., South Holland, IL 60473). I find myself referring to its step-by-step instructions on almost every detail of conventional construction.

For general plumbing, I would recommend *Plumber's Handbook* by Howard Massey ($11.50 from Craftsman Book Co., 542 Stevens Ave., Solana Beach, CA 92075). Good, easy-to-follow instructions. Also includes a section on how to install a septic system.

And what about wiring? An excellent (and inexpensive) wiring book is available from Sunset Books. It's called Basic Home Wiring Illustrated ($3.95, Lane Publishing Co., Willow & Middlefield Rds., Menlo Park, CA 94025). Also inexpensive books on paneling (*The Home Pro Paneling and Wallboard Guide*) and landscaping (*The Home Pro Landscape & Lawn Care Guide*) can be obtained at $2.95 each from Borden Publishing Co., 1855 W. Main St., Alhambra, CA 91801. These are two of the many 3M "Home Pro Guides." All reasonably priced, well written, and thorough.

For general concrete work, try *The Practical Handbook of Concrete and Masonry* by Richard Day ($4.95 from Arco, 219 Park Ave., S. New York, NY 10003).

Note that all prices are subject to change. Also, it's quite probable that, sooner or later, many of these books will be out of print. Thus in addition to purchasing these books for yourself, also consider adding them to your local library.

Appendix 2

In the following pages, you are invited to go on an imaginary "earth shelter" tour. Included are a number of house plans as well as some other kinds of earth-sheltered projects.

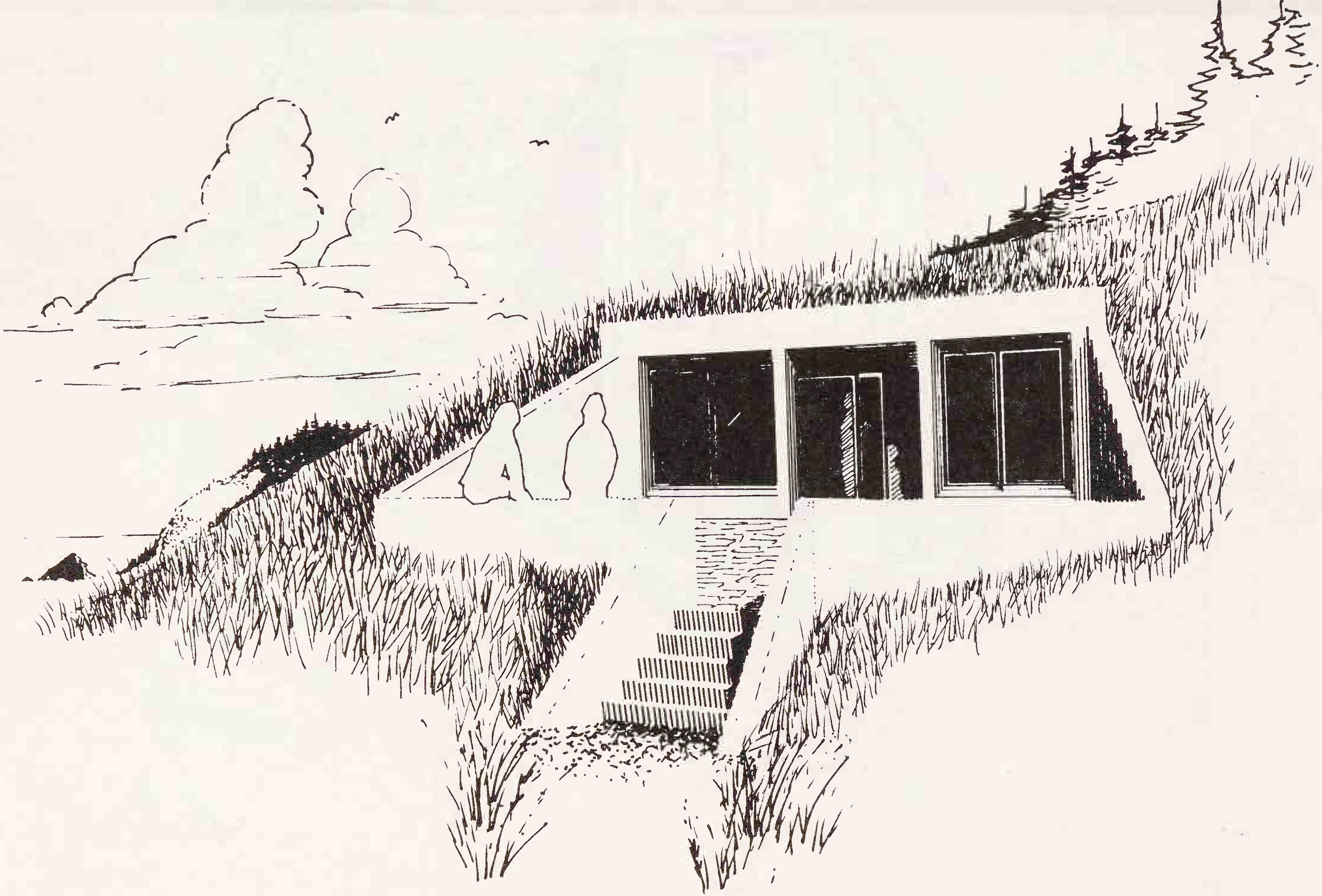
The five house designs and accompanying floor plans were chosen from approximately 100 such plans submitted by students at the University of Wisconsin-Stout in Menomonie, Wisconsin. The problem was to design a passive solar, earth-sheltered home with 800 to 1000 square feet of living space.

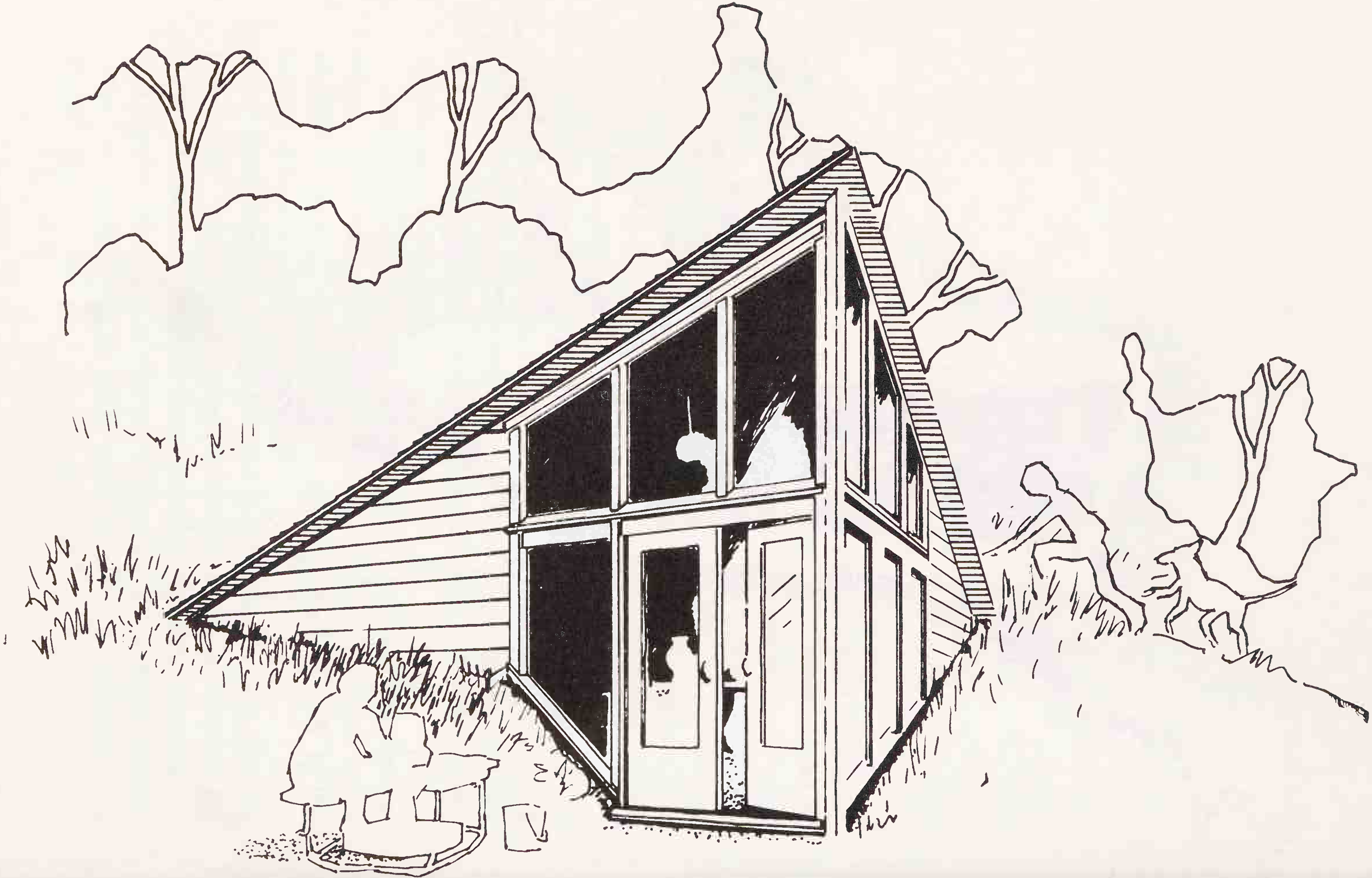
Each plan had to have a kitchen-dining area, living room, two bedrooms, a full bath, a vegetable larder, a room for mechanical equipment (laundry, hot water heater, pressure tank, etc.), a solar greenhouse, and finally, a single car garage with space for a small workshop.

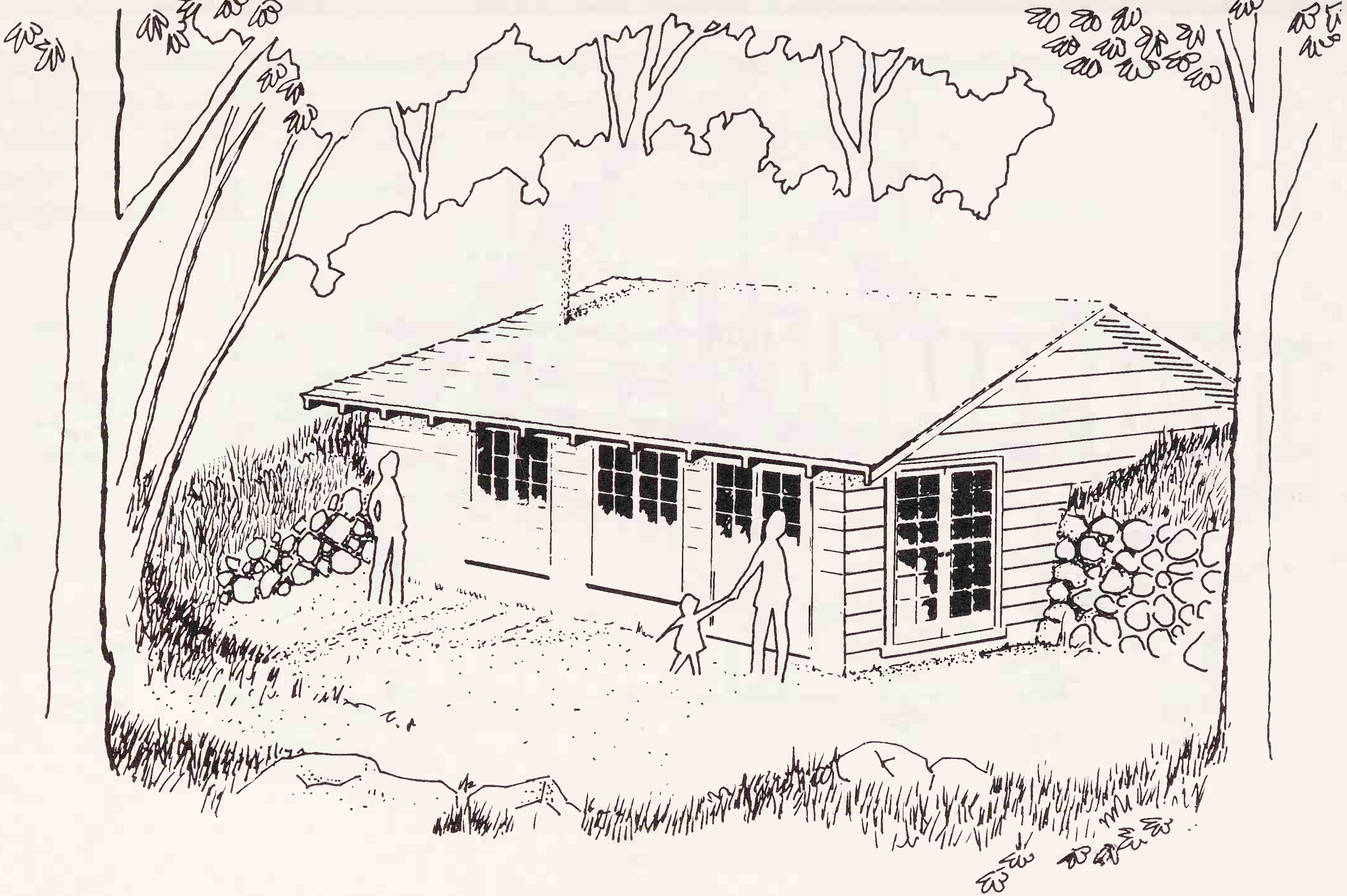
Designs and floor plans were selected on a criteria of aesthetics, energy efficiency, and convenience of room arrangement. In an attempt to keep overall costs at a minimum, all but one of the houses utilize a conventional roof.

See these designs not as the final word in layout, but more as interesting "window-shopping," so that you might identify attractive ideas to incorporate into your own earth-sheltered plans.

A sincere "thanks" to class coordinator Hans Timper, graphic artist Paul Hansen, and to all the students who participated in the project.







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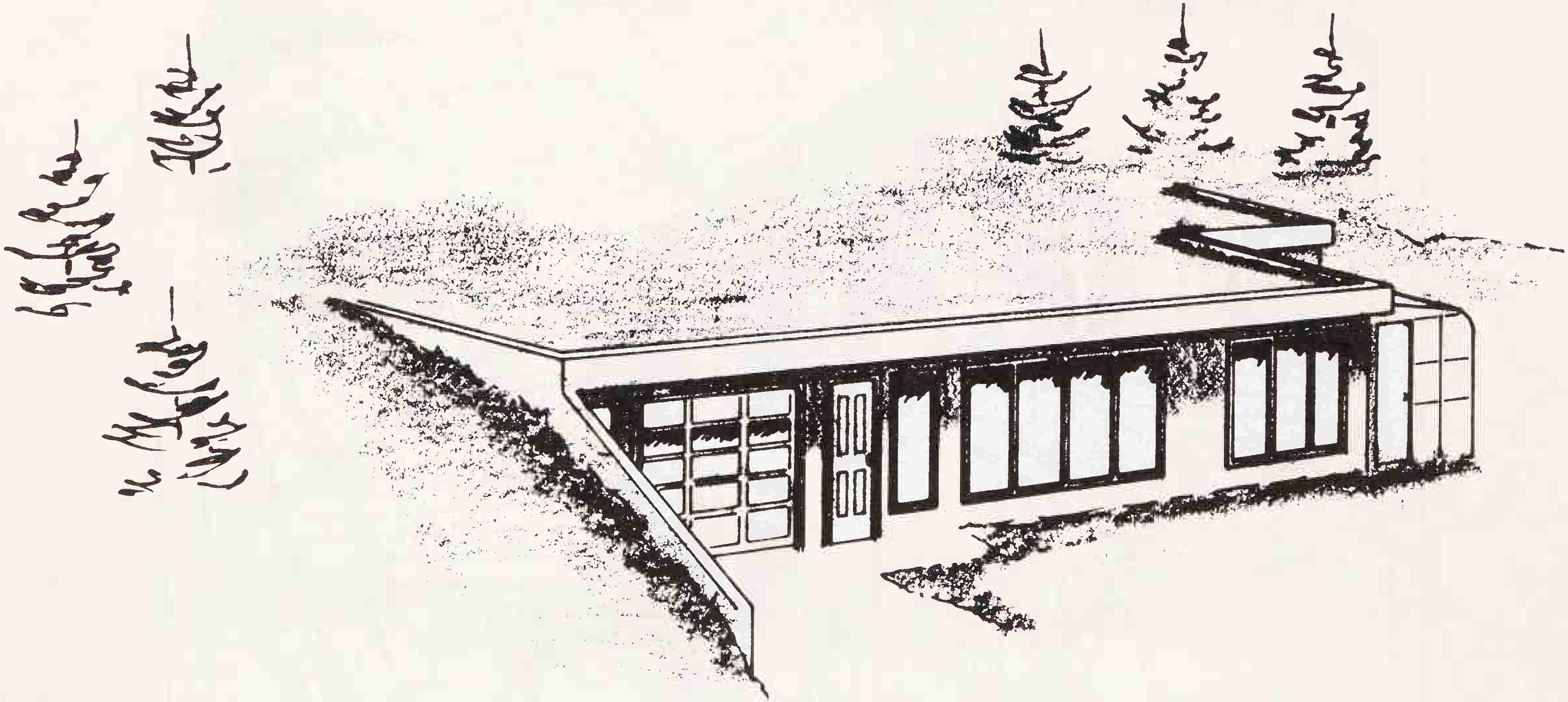

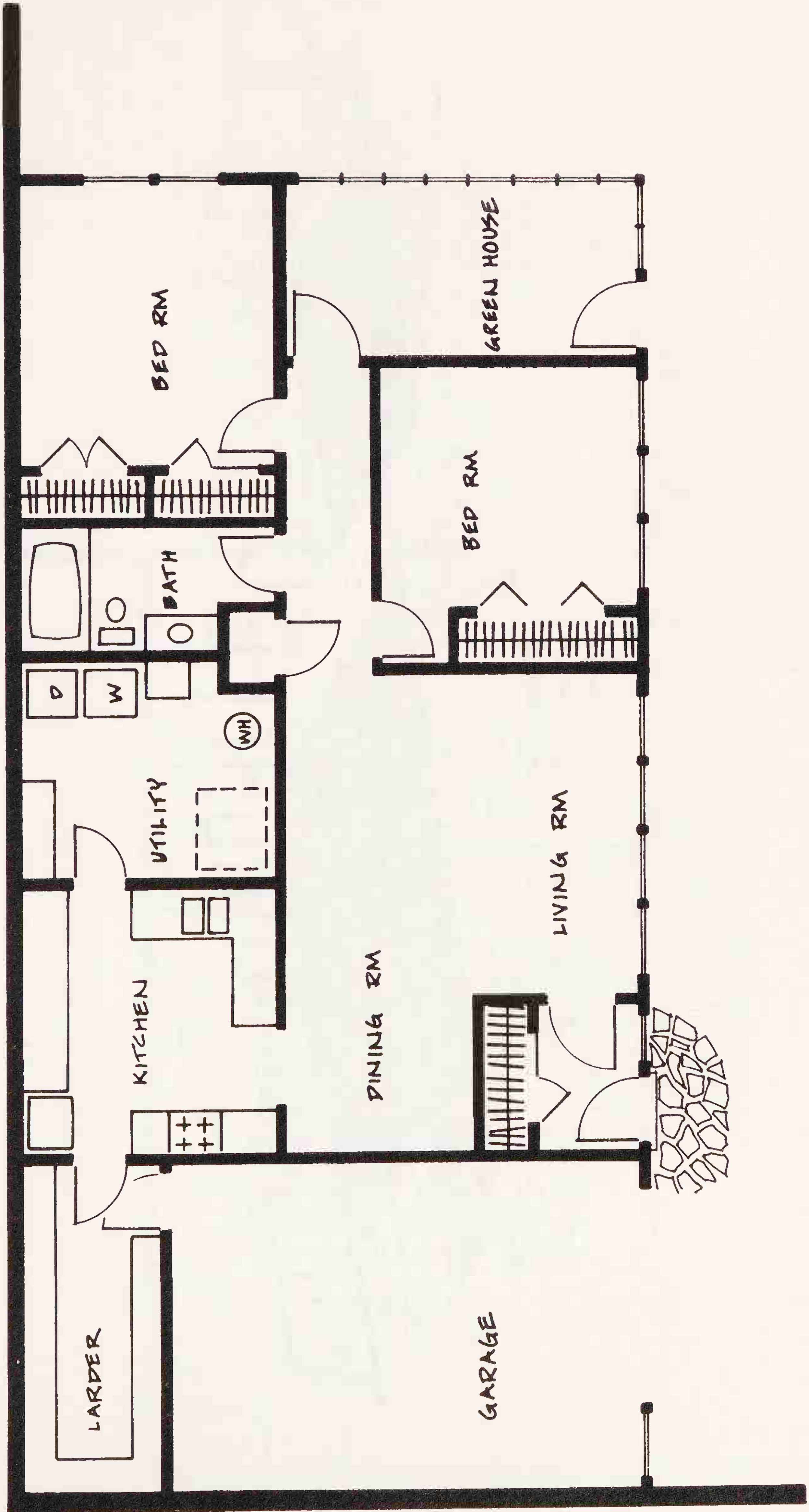
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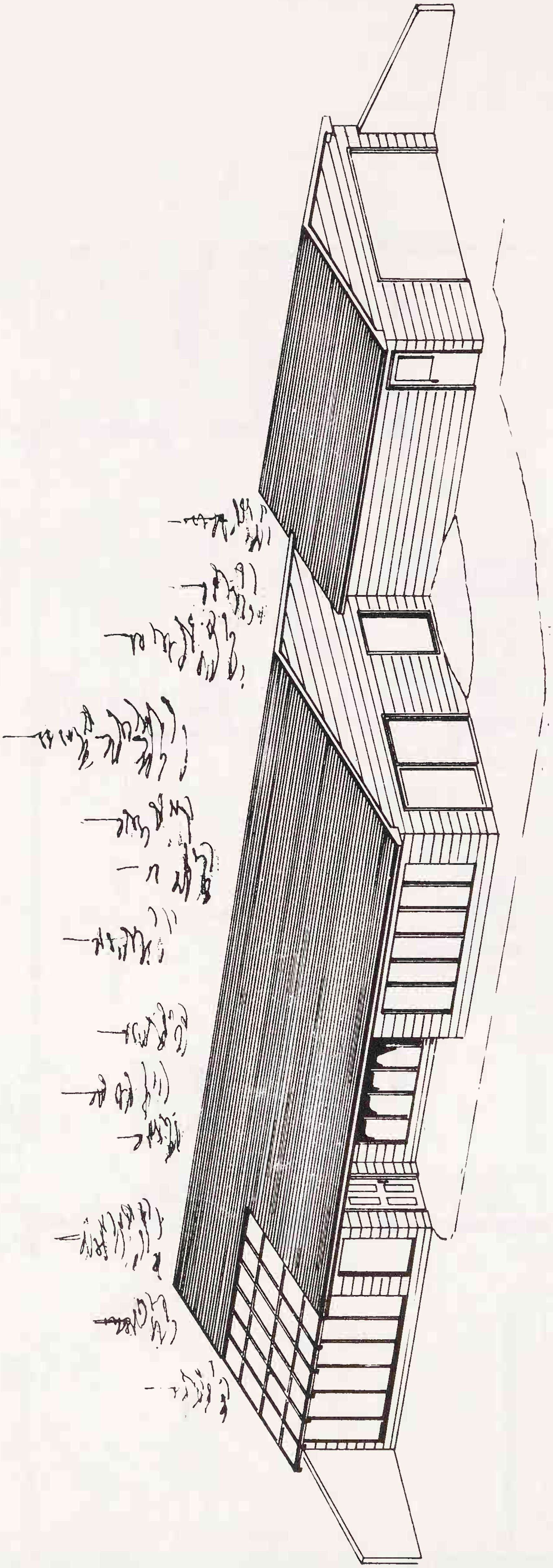

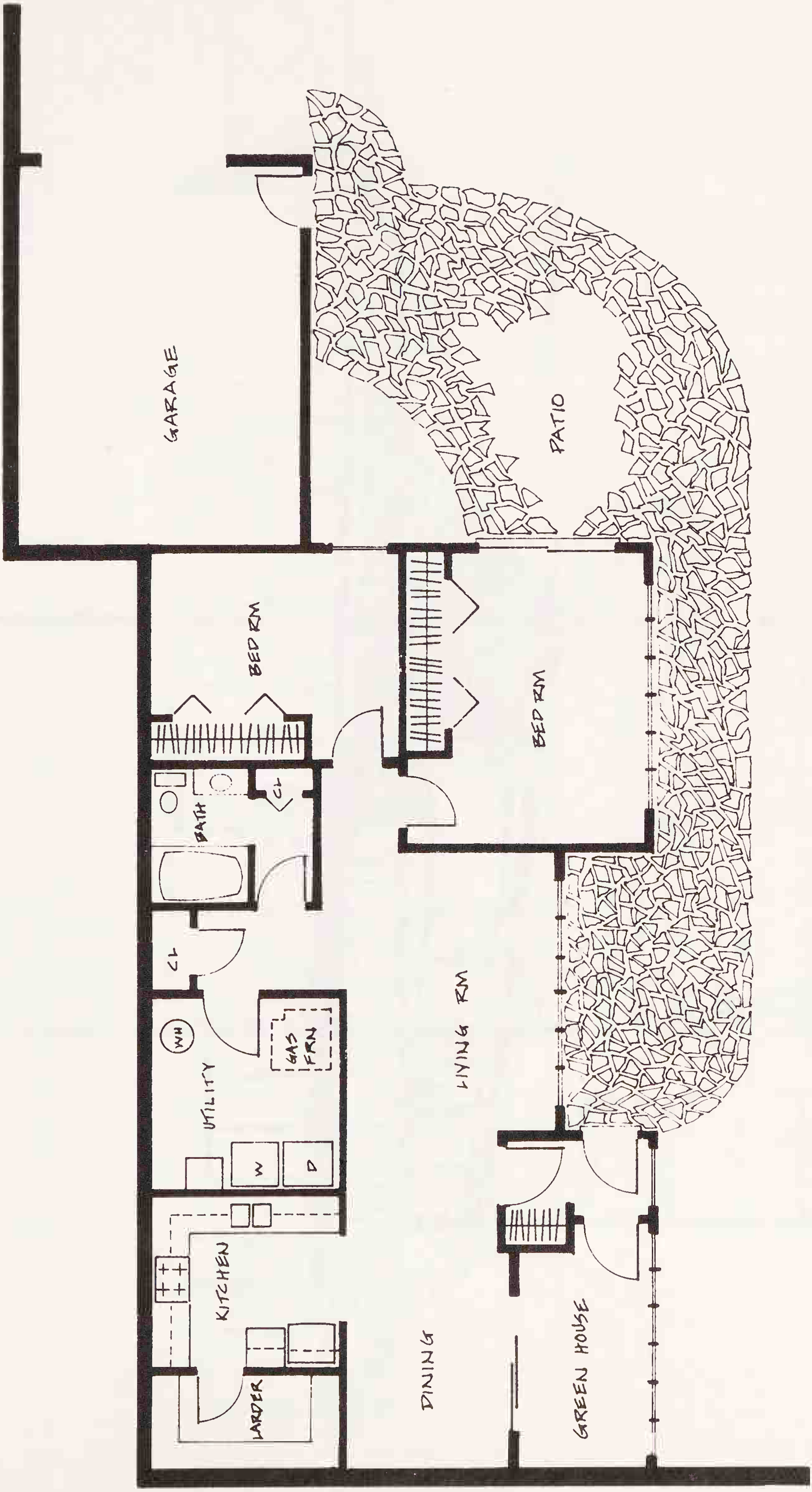
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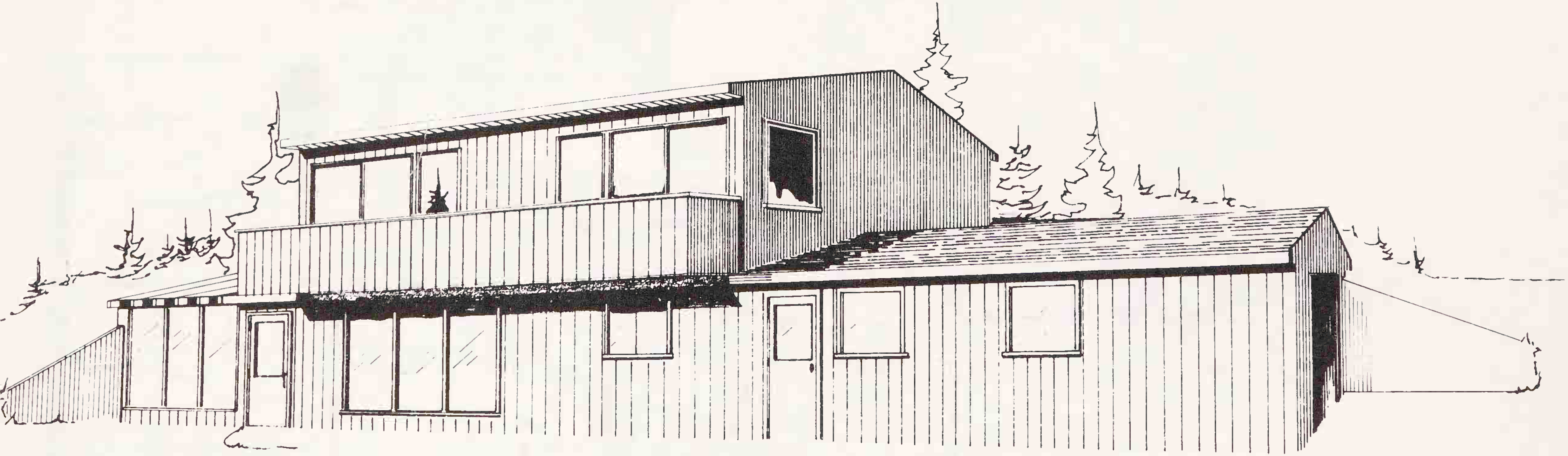

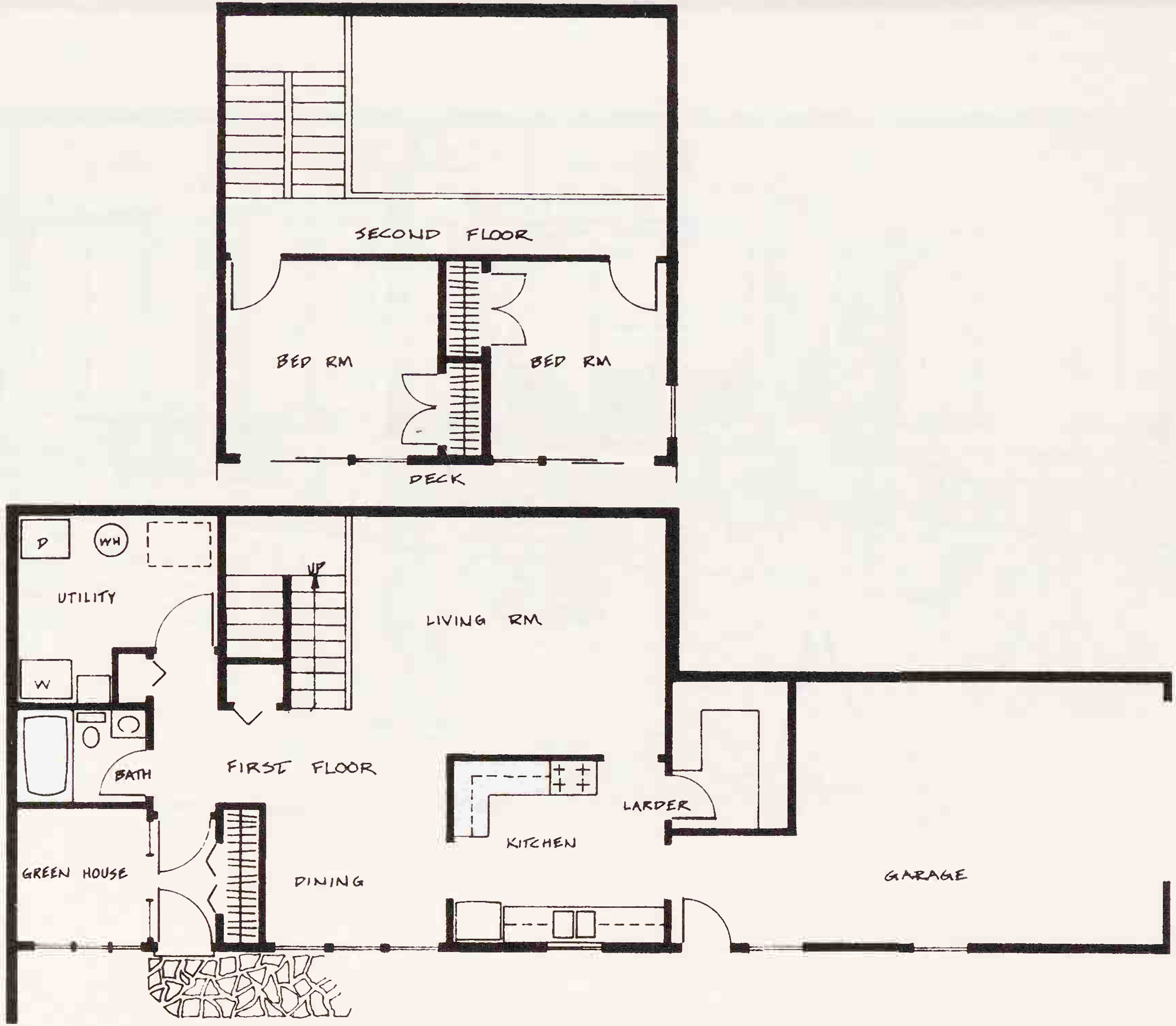
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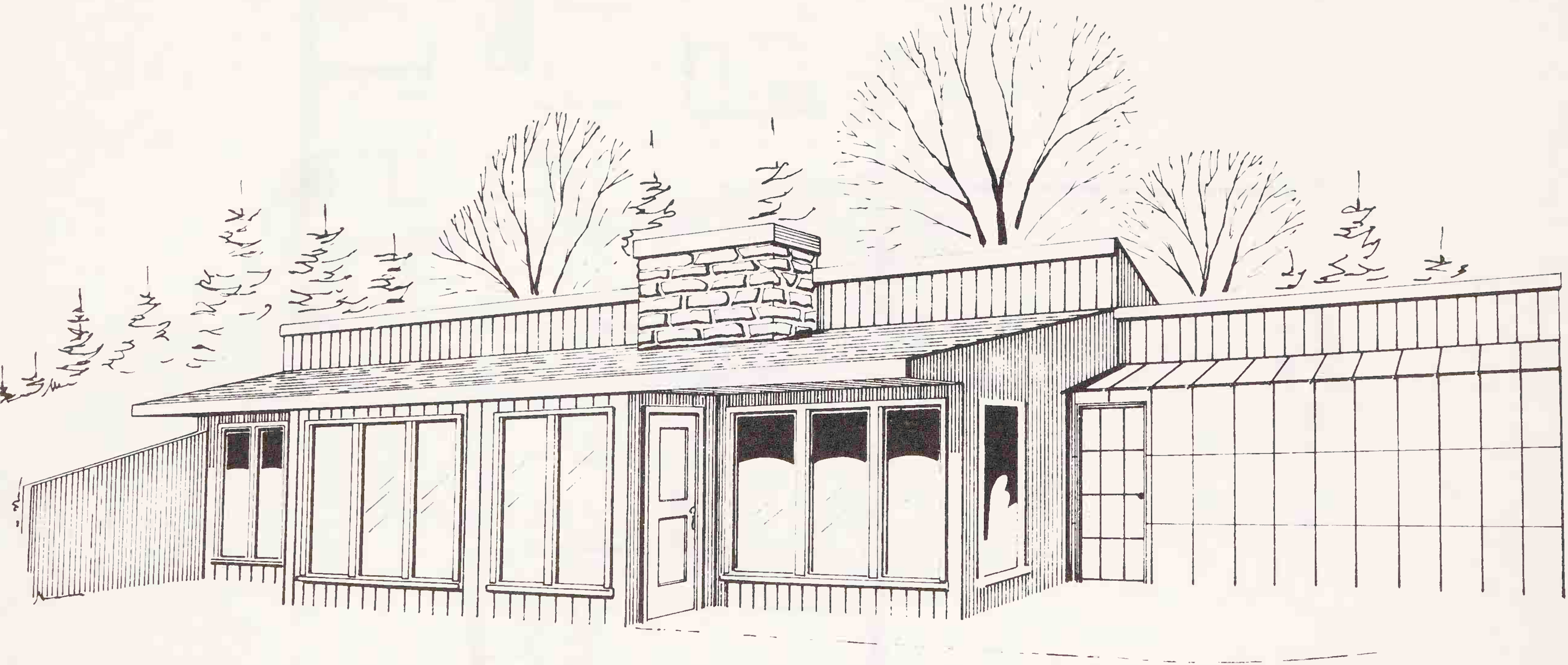

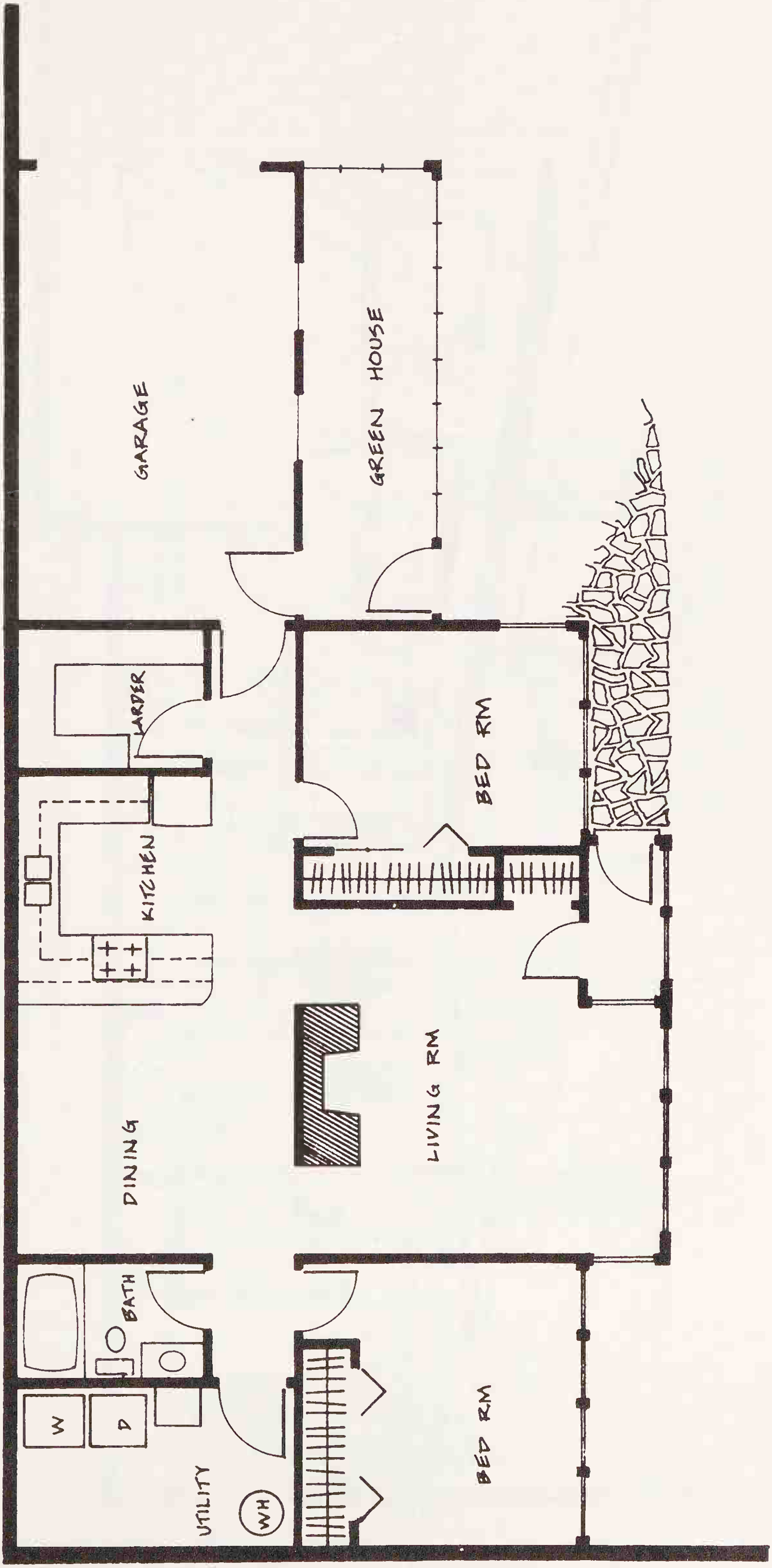
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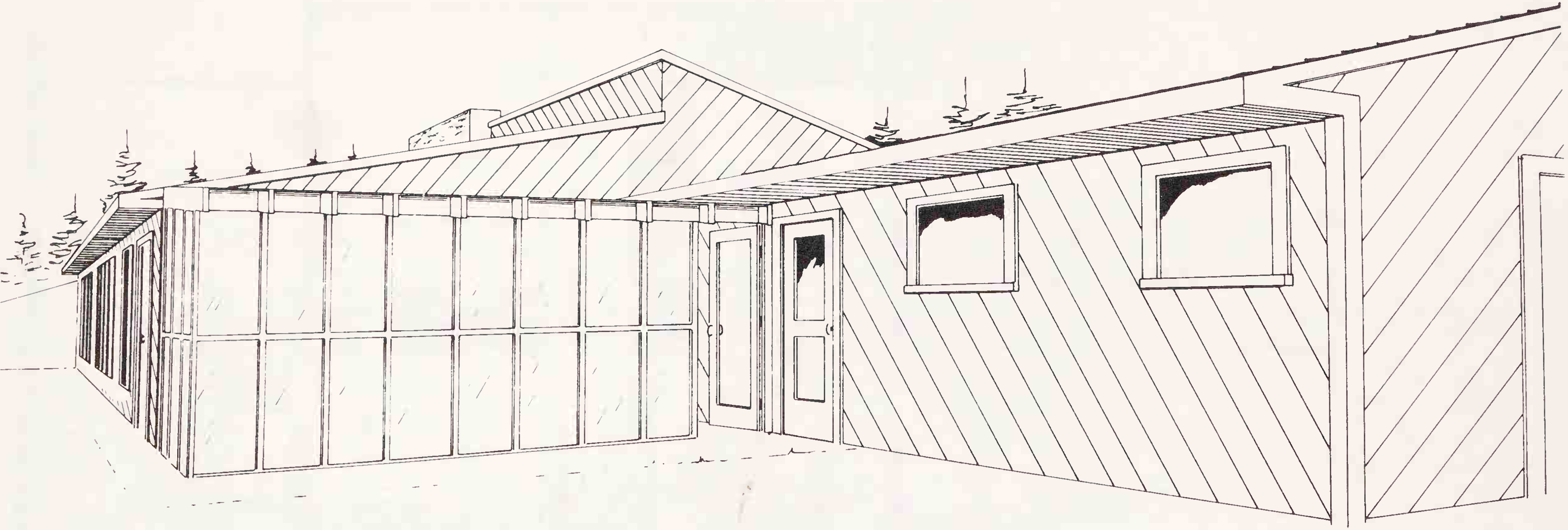

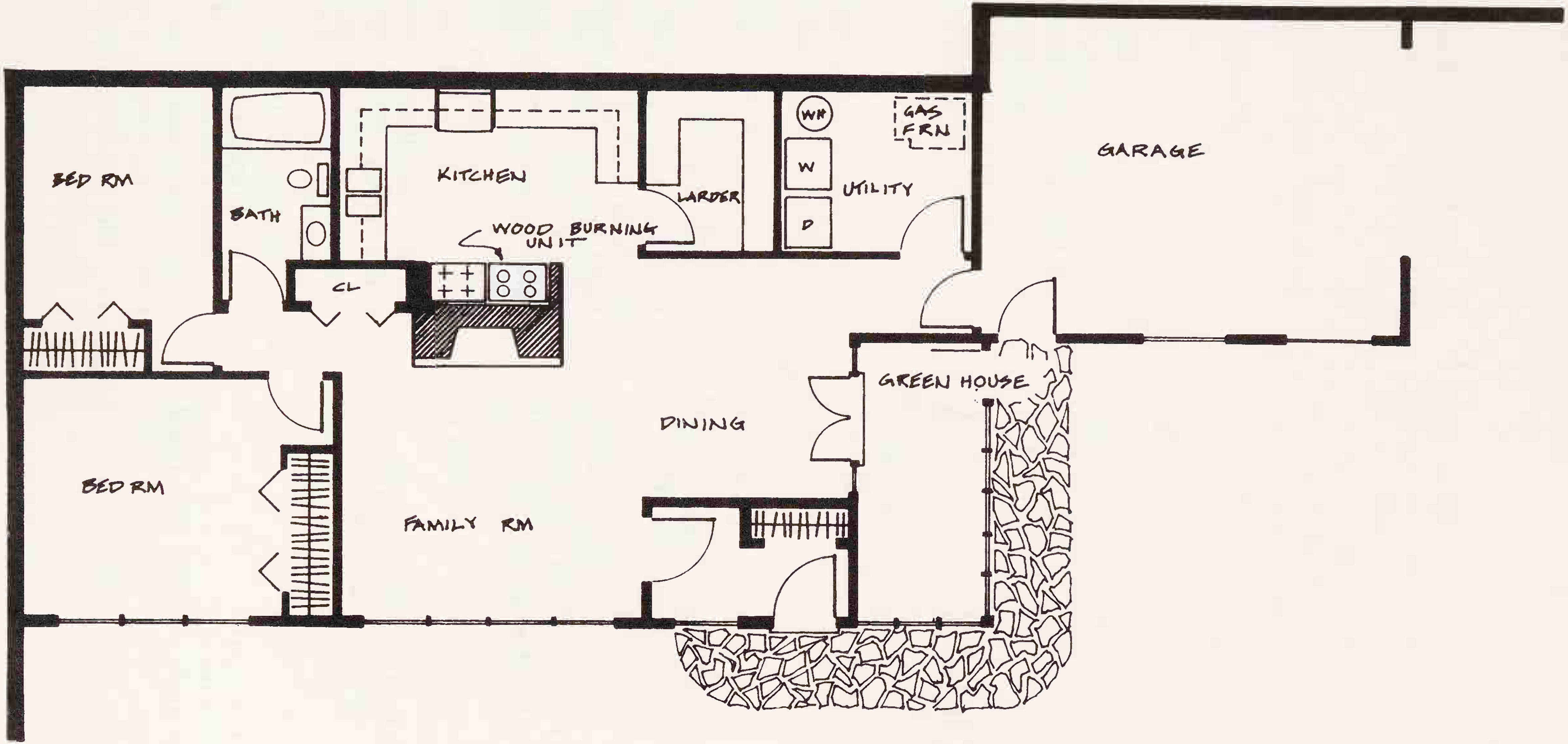
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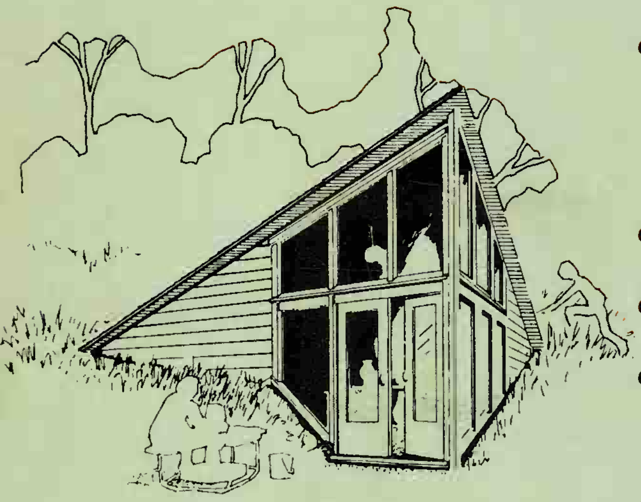

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About the Author

Jim Eggert, a professor of economics at the University of Stout - Wisconsin, built his earth-sheltered office two years ago. Not his first earth-sheltered project, he has lived with his family for the past eight years in a pole home he and his wife, Pat, built themselves. Other books to his credit are *What is Economics?*, *Investigating Microeconomics,* and *The No-Mortgage Home.*

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